FLORIDA GEOLOGICAL SURVEY

SECOND ANNUAL REPORT

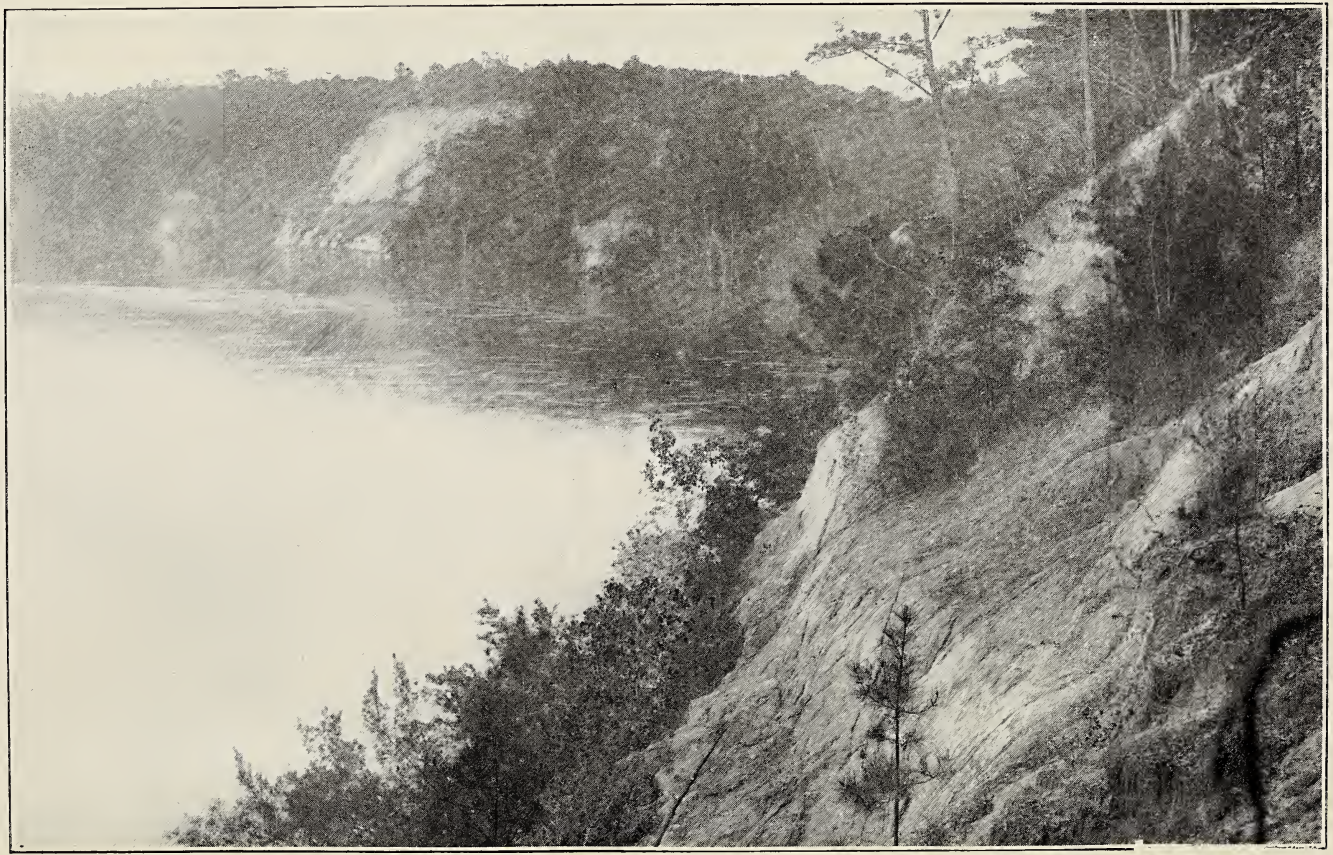


Photo by Sellards.

ALUM BLUFF, APALACHICOLA RIVER, FLA. LOOKING UP STREAM. THE SECTION GIVEN IN THE TEXT (p. 273) WAS MADE AT THE EXPOSURE SEEN IN THE DISTANCE.

FLORIDA STATE GEOLOGICAL SURVEY

E. H. SELLARDS, State Geologist

Second Annual Report

1908-09

ADMINISTRATIVE REPORT
MINERAL INDUSTRIES
STRATIGRAPHIC GEOLOGY

INCLUDING A TOPOGRAPHIC AND GEOLOGIC MAP OF FLORIDA
PREPARED IN CO-OPERATION WITH THE UNITED
STATES GEOLOGICAL SURVEY.

Smithsonian Institution
255796
U. S. National Museum

PUBLISHED FOR
THE STATE GEOLOGICAL SURVEY
TALLAHASSEE, 1909.

34317
ALLIED PRINTING
TRADES UNION LABEL COUNCIL
ST AUGUSTINE FLA

THE RECORD COMPANY
ST. AUGUSTINE
FLORIDA
1909

557.4
.F6F2
NH

LETTER OF TRANSMITTAL.

To His Excellency, Hon. Albert W. Gilchrist,
Governor of Florida.

Sir:—I have the honor to submit herewith a report of the operations of the State Geological Survey for the year ending June 30, 1909, constituting the second annual report of the State Geologist. In addition to the administrative report and the report on mineral industries, there is included a report on the geology of Florida with special reference to stratigraphy, to which is added a chapter on the topography and geology of Southern Florida. This report on stratigraphy has been prepared in cooperation with the United States Geological Survey carried on in accordance with plans mentioned in my former report. The Florida Survey has derived much benefit from this cooperative work and is fortunate in having the report for publication at this time.

Permit me to express my appreciation of the interest you have taken in the work of the State Geological Survey, and the assistance you have given in the prosecution of that work.

Very respectfully,
E. H. SELLARDS,
State Geologist.

Tallahassee, Florida.
October 1, 1909.

CONTENTS.

PAGE

ADMINISTRATIVE REPORT BY E. H. SELLARDS 13
- Members of the State Survey force 13
- Publications issued 13
- Distribution of reports 14
- Relation of the State Survey to other organizations 14
- The Survey library 15
- Exhibition of geological material 15
- The relation of the State Survey to the ownership of mineral bearing lands 15
- Samples sent to the Survey for examination 16
- Collection of statistical information 16
- Financial statement 17

A PRELIMINARY REPORT ON THE GEOLOGY OF FLORIDA, with special reference to the Stratigraphy, by GEORGE CHARLTON MATSON AND FREDERICK G. CLAPP. Prepared in cooperation between the United States Geological Survey and the Florida State Geological Survey, under the direction of THOMAS WAYLAND VAUGHAN

- Topography and drainage 28
  - General topographic features 28
    - Rivers 30
    - Lakes and swamps 31
  - Lake region 32
    - Caverns 32
    - Sink holes 34
    - Natural bridges 36
    - Sand dunes 37
    - Springs 37
  - North and West Florida 38
    - Erosion features 38
    - Lakes 38
    - Sand dunes 39
  - Coastal region 39
    - Streams and ponds 39
    - Ridges 39
    - Terraces 39
  - Shore lines 40
    - Coral reefs 40
    - Submerged continental border 40
    - Bars 40
    - Sounds 41
    - Inlets 41
    - Tidal runways 41
    - Capes 42
- Soils 43
  - Origin 43
  - Classification 44
- Structure 46
- Stratigraphic geology 50
  - Tertiary 50
    - Oligocene 50
      - Vicksburg group 50

Stratigraphic geology—Continued.

PAGE
Marianna and "Peninsular" limestones 52
  Stratigraphic position 52
  Lithologic character 52
  Thickness 53
  Physiographic expression 53
  Paleontologic character 54
  Structure 54
  Local details 54
Ocala limestone 59
  Stratigraphic position 60
  Lithologic character 60
  Thickness 61
  Physiographic expression 61
  Paleontologic character 61
  Structure 61
  Local details 61
  Miliolite limestone 66
Apalachicola group 67
Hawthorne formation 69
  Stratigraphic position 69
  Lithologic character 70
  Thickness 70
  Physiographic expression 71
  Paleontologic character 71
  Structure 71
  Local details 71
Chattahoochee formation 74
  Stratigraphic position 75
  Lithologic character 76
  Thickness 76
  Physiographic expression 76
  Paleontologic character 77
  Structure 78
  Local details 78
Tampa formation 84
  Stratigraphic position 86
  Lithologic character 86
  Thickness 87
  Physiographic expression 87
  Paleontologic character 87
  Structure 88
  Local details 88
Alum Bluff formation 91
  Stratigraphic position 92
  Lithologic character 92
  Thickness 94
  Physiographic expression 94
  Paleontologic character 95
  Structure 95
  Local details 95
    Chipola marl member 102

Stratigraphic geology—Continued.

PAGE
Oak Grove sand member ... 104
Shoal River marl member ... 104
Miocene ... 106
General remarks ... 106
Jacksonville formation ... 108
Stratigraphic position ... 108
Lithologic character ... 108
Thickness ... 110
Physiographic expression ... 111
Paleontologic character ... 111
Structure ... 111
Local details ... 112
Choctawhatchee marl ... 114
Stratigraphic position ... 114
Lithologic character ... 115
Thickness ... 116
Physiographic expression ... 116
Paleontologic character ... 116
Structure ... 116
Local details ... 117
Pliocene ... 123
Caloosahatchee marl ... 123
Stratigraphic position ... 124
Lithologic character ... 124
Thickness ... 124
Physiographic expression ... 124
Paleontologic character ... 124
Structure ... 125
Local details ... 126
Nashua marl ... 128
Stratigraphic position ... 128
Lithologic character ... 129
Thickness ... 129
Physiographic expression ... 129
Paleontologic character ... 129
Structure ... 130
Local details ... 130
Alachua clay ... 133
Stratigraphic position ... 134
Lithologic character ... 134
Thickness ... 134
Physiographic expression ... 134
Paleontologic character ... 135
Structure ... 135
Local details ... 135
Bone Valley gravel ... 138
Stratigraphic position ... 139
Lithologic character ... 139
Thickness ... 139
Physiographic expression ... 140
Paleontologic character ... 140

Stratigraphic geology—Continued.

PAGE
- Structure 140
- Local details 140
- Pliocene (?) 141
  - Lafayette formation 141
    - Stratigraphic position 141
    - Lithologic character 142
    - Thickness 143
    - Physiographic expression 143
    - Paleontologic character 143
    - Structure 143
    - Local details 143
- Quaternary 145
  - Pleistocene 146
    - Fossiliferous marls 146
      - General 146
      - Local details 148
    - Gray sand 152
    - Planorbis rock 153
    - Coquina 153
    - Vermetus rock 154
    - Yellow sand 155
    - Stratigraphic position 155
    - Thickness 156
    - Physiographic expression 157
    - Paleontologic characters 157
    - Structure 157
- Recent 157
  - Alluvial deposits 157
  - Lacustrine deposits 158
  - Vermetus rock 158
  - Beach deposits 158
  - Aeolian deposits 159
  - Chemical deposits 159
  - Human remains 160
- General Geologic History 162

TOPOGRAPHY AND GEOLOGY OF SOUTHERN FLORIDA, by SAMUEL SANFORD.

- Introduction 177
- Acknowledgments 178
- Object of Report 178
- Topography 179
  - General features 179
  - Shape of the land mass 180
  - Features of the mainland 180
  - Pinelands 181
  - Dunes 182
  - Rolling sand plains 185
  - Flat lands 186
  - Rock ridges 186
  - Swamps 188
    - Everglades 189
      - Elevation 190

Topography—Continued.

PAGE
        Bedrock surface 191
            Origin 193
        Cypress swamps 193
        Coastal swamps 194
    The keys 195
    The Florida reef 196
    Shore line topography 198
    Waste and growth of the mainland and keys........ 200
    Recent changes of level........ 201
Geology 202
    General statement 202
    Pre-Pleistocene formations 203
        General statement 203
        Evidence from well records........ 203
            Palm Beach 204
            Key Vaca 204
            Key West 205
            Buck Key 206
Oligocene 207
    Thickness 207
Miocene and Pliocene 207
    Lithology 207
    Thickness 207
    Source of siliceous materials........ 207
Pleistocene 208
    Unexposed beds 208
    Exposed beds 209
Palm Beach limestone 209
    Synonymy 209
    Stratigraphic position 209
    Lithologic characteristics 210
    Thickness 210
    Physiographic expression 210
    Paleontologic characteristics 210
    Areal distribution 210
    Structure 211
Miami oolite 211
    Synonymy 211
    Stratigraphic position 212
    Lithologic characteristics 212
    Thickness 212
    Physiographic expression 213
    Paleontologic characteristics 213
    Areal distribution 213
    Structure 213
    Correlation 214
Key Largo limestone 214
    Synonymy 214
    Stratigraphic position 215
    Lithologic characteristics 216
    Thickness 216
    Physiographic expression 217

Key Largo limestone—Continued.

PAGE
  Paleontologic characteristics 217
  Areal distribution 217
  Exposures 218
Key West oolite 218
  Synonymy 218
  Stratigraphic position 219
  Lithologic characteristics 219
  Thickness 219
  Physiographic expression 220
  Paleontologic characteristics 220
  Areal distribution 221
Origin of Florida oolites 221
Lostmans River limestone 222
  Synonymy 222
  Stratigraphic position 223
  Lithologic characteristics 223
  Thickness 223
  Areal distribution 224
  Origin 224
Coquina 225
Sands 226
Lithology of Pleistocene beds 227
Thickness of Pleistocene beds 227
Recent 228
  Peat 228
  Marl 228
  Sands 229
  Coral reefs 229
  Worm rock 230
  Oyster banks 230
Pleistocene and Recent History of Southern Florida 231

MINERAL INDUSTRIES, by E. H. Sellards.

Phosphate 235
  Varieties 235
  Location 235
  Production for 1908 236
  Loss of phosphate in mining 240
Clay 242
  Plastic kaolin or ball clay 242
  Brick making clay 243
Peat 243
Diatomaceous earth 244
Lime and ground limestone 245
Sand-lime brick 245
Building stone 246
Materials for mortar and concrete 247
Minerals new to the State 250
  Malachite 250

THE FULLERS EARTH DEPOSITS OF GADSDEN COUNTY, with Notes on similar Deposits found elsewhere in the State, by E. H. Sellards and Herman Gunter.

Preface 255

The fullers earth deposits—Continued.

PAGE
Introduction 257
Mineral constituents of fullers earth 257
Physical properties 258
Tests 258
Uses 259
Methods of mining 259
Production of fullers earth 260
Discovery of fullers earth in America 260
Fullers earth deposits of Florida 261
Gadsden County 261
Geography and topography 261
Geology 263
The Apalachicola River section 265
Section at Chattahoochee Landing and in the vicinity of Chattahoochee and River Junction 267
Section at Aspalaga Bluff 271
Section at Rock Bluff 273
Section at Alum Bluff 275
Minor folds in the Chattahoochee limestone 277
Dip of the Chattahoochee limestone 277
The Ocklocknee River section 279
Fullers earth outcrops in Gadsden County 280
Section in Owl Commercial Co.'s pit at Quincy 282
Section on public road one mile east of Quincy 283
Section on Quincy-Attapulgus road, five miles northeast of Quincy 283
Section one mile west of Gatzlaff on west side of Attapulgus Creek 283
Section at public road crossing on Bear Creek 283
Section on Crooked Creek 283
Section at Nicholson 284
Amount of fullers earth in Gadsden County 285
Liberty County 285
Notes on fullers earth 286
Leon County 286
Notes on fullers earth 286
Columbia County 287
Notes on fullers earth 287
Alachua County 287
Notes on fullers earth 288
Section at "Devil's Mill Hopper" 288
Marion County 288
Notes on fullers earth 289
Section at Belleview 289
Manatee County 289
Notes on fullers earth 289
Sections in pit of Atlantic Refining Company 290
Section at the abandoned pit of the Columbia Fullers Earth Company 291
Amount of fullers earth in Florida 291
Index 293

ILLUSTRATIONS.

PLATES.

PLATE. FACING PAGE.
I. Alum Bluff on Apalachicola River, Florida .... Frontispiece
II. Fig. 1. Sink hole, southeast of Vernon. Type of topography of Vicksburg group 58
Fig. 2. "Falling Water," five miles south of Chipley 58
III. Fig. 1. Ocala limestone. Quarry of Ocala Lime Company. 64
Fig. 2. Ocala limestone ledge in pit of Fort White Hard Rock Phosphate Company, Fort White 64
IV. Fig. 1. Outcrop of Hawthorne limestone on Suwanee River opposite Ellaville 74
Fig. 2. Limestone of Tampa formation, Hillsboro County. 74
V. Fig. 1. Cut on the G. S. and F. R. R., near Kent, Nassau County 100
Fig. 2. Alum Bluff formation, near White Springs on Suwanee River 100
VI. Fig. 1. Land pebble phosphate, showing bedded deposit.... 140
Fig. 2. Pleistocene terrace, St. Marys River.............. 140
VII. Fig. 1. Conglomerate of Lafayette formation, Rock Hill.. 154
Fig. 2. Coquina rock, Anastasia Island, St. Augustine..... 154
VIII. Fig. 1. "Rise" of the Santa Fe River..................... 160
Fig. 2. Ancient shell mound, Indian River................ 160
IX. Fig. 1. Quarry in Miami oolite, Keys Station, Dade County 212
Fig. 2. Reef rock overlain by marl, Knights Key.......... 212
X. Fig. 1. Erosion by spray in Key Largo limestone, Knights Key 218
Fig. 2. Beach ridge of calcareous sand, Cape Sable........ 218
XI. Hard rock phosphate mining region...................... 236
XII. Land and River pebble phosphate mining region........... 238
XIII. Fig. 1. Plate rock phosphate mining, Anthony, Marion County 240
Fig. 2. Removing overburden, land pebble phosphate, Mulberry 240
XIV. Fig. 1. Plastic Kaolin mine, Edgar, Putnam County....... 244
Fig. 2. Dredge excavating peat, North Canal, near Fort Lauderdale. Photo by Matson.................. 244
XV. Fig. 1-6. Sands for mortar 248
XVI. Fig. 1. Fullers earth plant at Ellenton, Manatee County... 258
Fig. 2. Fullers earth plant at Quincy, Gadsden County... 258
XVII. Fig. 1. Apalachicola River looking south from Alum Bluff. 236
Fig. 2. Exposure of Chattahoochee limestone on A. C. L. R. R. River Junction.......................... 266
XVIII. Map of fullers earth exposures in Gadsden and Liberty Counties 281
XIX. Fig. 1. View in pit of Owl Commercial Company, Quincy. 284
Fig. 2. View in pit of Owl Commercial Company, Quincy. 284

TEXT FIGURES.

PAGE.
Fig. 1. Map showing sink holes................................. 33
Fig. 2. Solution channel in limestone.......................... 36
Fig. 3. Section along drainage canal........................... 193
Fig. 4. Section at Chattahoochee Landing....................... 268
Fig. 5. Section at Aspalaga Bluff.............................. 272

MAP.

Topographic and Geologic Map of Florida..................... In pocket

FLORIDA STATE GEOLOGICAL SURVEY.

E. H. SELLARDS, STATE GEOLOGIST.

ADMINISTRATIVE REPORT.

The members of the State Survey force during the past year have been, in addition to the State Geologist, Mr. Herman Gunter, Dr. R. M. Harper, and during a part of the year Professor N. H. Cox. The chemical analyses necessary to the work of the State Survey are made by the State Chemist.

Mr. Gunter has assisted in the preparation of the paper on fullers earth deposits which accompanies this report. In addition he has had charge of cataloguing and recording the Survey collections.

Dr. Harper's connection with the Survey began in December, 1908, since which time he has been engaged in an investigation of the peat resources of the State. The peat deposits form a natural resource the value of which can not fail to be appreciated as other fuels become exhausted, and Dr. Harper's report will do much to further the development of this industry. The fuel tests of peat samples for this purpose are being made in the fuel testing laboratory of the United States Geological Survey.

Professor N. H. Cox, of the department of civil engineering of the State University, was engaged during the summer of 1908 in an investigation of the roads and road making materials of the State.

In addition to the necessary correspondence and administrative work of the office, the State Geologist has completed the field investigations for a preliminary report on the fullers earth deposits, and has carried on field work with a view to the publication of a report on the phosphate deposits.

PUBLICATIONS ISSUED.

Two publications have been issued during the year as follows: The First Annual Report covering the operations of the State Geological Survey for the year 1908-09, and Bulletin No. 1 of the Survey, on the underground water supply of central Florida.

The annual report contains: (1) A sketch of the geology of Florida; (2) a chapter on mineral industries, including phosphate, kaolin or ball clay, brick-making clays, fullers earth, peat, lime and cement, and road making materials; (3) a bibliography of publications on Florida geology with a review of the more important papers published previous to the organization of the present Geological Survey.

The bulletin contains: (1) Underground water: general discussion; (2) the underground water of central Florida, deep and shallow wells, springs and artesian prospects; (3) effects of underground solution, cavities, sink-holes, disappearing streams, and solution basins; (4) drainage of lakes, ponds and swamp lands, and disposal of sewage by bored wells. Water analyses are included as well as tables, giving general water resources, public water supplies, spring and well records.

DISTRIBUTION OF REPORTS.

The reports issued by the Survey are distributed upon request to citizens and to city and to other public libraries. The results of the Survey thus become permanently available to those interested in the geology or mineral resources of the State.

RELATION OF THE STATE SURVEY TO OTHER ORGANIZATIONS.

U. S. Geological Survey:—Cooperation with the National Geological Survey was arranged soon after the organization of the State Survey. During 1907-08 this cooperative work was devoted chiefly to an investigation of the general geology and stratigraphy of the State and the underground water supply. Bulletin No. 1 already referred to formed a part of the results of this cooperative work. A special report on the stratigraphy of the State forming a second part of this cooperative work accompanies this report. During the present year the State Survey has fortunately been able to extend cooperation with the National Survey to include testing of peat samples for fuel purposes. These tests form a part of and will be included in the report on peat deposits.

U. S. Department of Agriculture:—The Director of the Division of Roads and Road Materials of the U. S. Department of Agriculture has very kindly consented to make the necessary tests of samples of road material of Florida taken in connection with the investigation of roads and road material by the Florida Survey.

Geological Surveys of Neighboring States: — Geological formations are limited by no such lines as State boundaries, and an intelligent study of a formation often necessitates a knowledge of its extent and development in a neighboring State. The relationship of a State Survey is therefore close with neighboring States, and particularly with adjoining States. This relationship in the case of the Florida Survey is especially close with Georgia and Alabama. With more distant States there is a no less real relationship growing out of a similarity of deposits, and of methods of study and development.

Office of State Chemist:—The Survey law provides that analytical work necessary to the investigations of the Survey shall be done by the State Chemist. The Survey is thus brought into co-operative relation with the Division of Chemistry of the Department of Agriculture and in so far as the work of the Survey contributes to agricultural interests, to the Department of Agriculture as a whole.

The State Agricultural Experiment Station:—In its study of the water supply in relation to agriculture, of soils in their geological relations, and in other ways, the work of the State Survey may be expected to supplement certain lines of work of the State Experiment Station, the two organizations being of mutual aid to each other.

State Colleges and Other Educational Institutions: — The State Survey law provides that duplicate suits of specimens obtained by the Survey illustrating the geological and mineral features of the State shall be deposited with the State Colleges. The publications of the State Survey are placed in the libraries of all of the educational institutions desiring them.

THE SURVEY LIBRARY.

A well-equipped reference library is essential to the best results and an effort is being made to bring together those publications which are necessary to the immediate and future work of the Survey. The Survey library now contains more than 1,500 volumes. These include the reports of the several State Geological Surveys; the Annual Reports, Bulletins, Monographs, Professional Papers, Water Supply and Irrigation Papers, and other publications of the National Geological Survey; the reports of the Canadian, and a few other foreign Geological Surveys; and many miscellaneous volumes and papers on geological subjects. Additions to the Survey library will be appreciated.

EXHIBITION OF GEOLOGICAL MATERIAL.

The Survey law provides for the exhibition of geological material. The space available for this purpose is unfortunately as yet very limited. A part of one room has, however, been used for this purpose. Three cases have been built, designed to serve the double purpose of storage and exhibition, the lower part of the case being adapted to the purpose of storing material. In making the collections a systematic plan has been followed to secure a representation of the rocks, minerals, and fossils of each formation in the State. The collections will be added to as opportunity permits.

THE RELATION OF THE STATE SURVEY TO THE OWNERSHIP OF MINERAL-BEARING LANDS.

The relation of the State Survey to the ownership of mineral-bearing lands is specifically defined. The Survey law provides that it shall be the duty of the State Geologist and his assistants, when they discover any mineral deposits or substance of value, to notify the owners of the land upon which such deposits occur before disclosing their location to any other person or persons. Failure to do so is punishable by fine and imprisonment. It is not intended by the law, however, that the State Geologist's time shall be devoted to examinations and reports upon the value of private mineral lands. Reports of this character are properly the province of commercial geologists, who may be employed by owners of land for that purpose. To accomplish the best results, the work of the Survey must be in accordance with definite plans by which the State's resources are investigated in an orderly manner. Only such examinations of private lands can be made as constitute a part of the regularly planned operations of the Survey.

SAMPLES SENT TO THE SURVEY FOR EXAMINATION.

Samples of rocks, minerals and fossils will be at all times gladly received, and reported upon. Attention to inquiries and general correspondence are a part of the duties of the office, and afford a means through which the Survey may in many ways be useful to the citizens of the State.

The following suggestions are offered for the guidance of those submitting samples:

1. The exact location of all samples should be given. This should be carefully written out in full and placed on the *inside* of the package.
2. The statement accompanying the sample should give the conditions under which the specimen occurs, whether an isolated fragment or part of a larger mass or deposit.
3. Each package should be addressed to the Florida State Geological Survey, Tallahassee. The name and address of the sender should be plainly written on the outside.
4. Transportation charges, whether by mail, express or freight, should in all cases be prepaid.

THE COLLECTION OF STATISTICAL INFORMATION.

For many purposes the collection and publication of statistical information is helpful, both to the industries concerned and to the general public. Such statistical information is desired from all the mineral industries of the State. Such information will be recognized as strictly confidential in so far as it relates to the private business of any individual or company, and will be used only in making up State and County totals. The co-operation of the various industries of the State is invited in order that the best possible showing of the State's products may be made annually.

FINANCIAL STATEMENT.

The total appropriation for the State Geological Survey is $7,500 per annum. With the exception of the salary of the State Geologist the amount of which is fixed by statute, all Survey accounts are paid upon warrant issued by the Comptroller as per itemized vouchers approved by the Governor. The following is a list of the expenses of the Survey for the year ending June 30, 1909. The original of all bills and the itemized statements of all expense accounts are on file in the office of the Comptroller. Carbon copies of the same are on file in the office of the State Geologist:

July, 1908.	
E. H. Sellards, salary for the quarter ending June 30, 1908, chargeable to funds of the year covered by this report	$ 189.46
Herman Gunter, Assistant, salary, June, 1908	75.00
Nellie Mathes, stenographer, salary, June, (half month)	30.00
E. H. Sellards, State Geologist, expenses, May and June, 1908	57.65
Herman Gunter, traveling expenses, June, 1908	36.35
John McDougall, postage	13.49
Herrick and Cowell, peat testers	24.00
E. P. Greene, Arcadia, Fla., tripod	3.00
Eimer and Amend, supplies	8.90
American Peat Society, journal	2.00
W. H. Lowdermilk, Washington, publications	1.87
Hill Publishing Company, publications	8.20
University of Chicago Press, Journal of Geology	3.00
S. H. Coleman, Tallahassee, painting sign	4.10
G. E. Stechert and Company, publications	14.25
Iowa Geological Survey, publications	13.75
Economic Geology Publishing Company, Economic Geology	3.00
Capital Publishing Company, printing	40.25
N. H. Cox, Assistant, salary ($58) and expenses ($67.35), July 1-18	125.35
Nellie Mathes, stenographer, salary, July (two-thirds month)	40.00
Capital City Livery Stables, drayage	1.80
August, 1908.	
E. H. Sellards, State Geologist, traveling expenses, July and August	46.94
Nellie Mathes, stenographer, salary, August	60.00
Geological Society of America, publications	1.40
The H. & W. B. Drew Co., supplies	6.60
September, 1908.	
E. H. Sellards, salary for the quarter ending Sept. 30, 1908	625.00
Herman Gunter, Assistant, salary, July to September	225.00
Nellie Mathes, stenographer, salary, September	60.00
N. H. Cox, Assistant, salary ($30) and expenses ($30), August 3-13	60.00
Minnie Milligan, stenographic work	9.18
Capital Publishing Co., printing	573.60
Maurice-Joyce Engraving Co., engravings	62.98
Carried forward	$2,426.12

Brought forward	$2,426.12
October, 1908.	
E. H. Sellards, State Geologist, traveling expenses, Sept.-Oct.	60.01
Nellie Mathes, stenographer, salary, October	60.00
Gilmore and Davis, office supplies	13.45
W. H. Lowdermilk & Co., publications	21.25
Capital Publishing Co., printing	512.00
Capital Publishing Co., printing	2.50
John McDougal, Postmaster, postage	150.00
November, 1908.	
E. H. Sellards, State Geologist, traveling expenses, November	62.94
Nellie Mathes, stenographer, November	60.00
Munson Supply Co., typewriter keys	3.50
December, 1908.	
E. H. Sellards, State Geologist, traveling expenses, December	61.90
E. H. Sellards, salary for the quarter ending Dec. 31, 1908	625.00
Herman Gunter, Assistant, salary, October-December	225.00
R. M. Harper, Assistant, salary ($100.00), expenses ($72.24)	172.24
The D. R. Cox Furniture Co., supplies	5.03
Engineering and Mining Journal, publications	1.00
J. K. Small, publications	4.12
Board of Managers, City Water and Light Plants, supplies	13.10
January, 1909.	
E. H. Sellards, State Geologist, traveling expenses, January	41.50
R. M. Harper, Assistant, traveling expenses ($39.81), salary ($100).	139.81
Herman Gunter, Assistant, traveling expenses ($8.65), salary ($75).	83.65
February, 1909.	
E. H. Sellards, State Geologist, traveling expenses, February	96.89
R. M. Harper, Assistant, traveling expenses ($60.25), salary ($100).	160.25
Herman Gunter, Assistant, traveling expenses ($34.89), salary ($75)	109.89
Nellie Mathes, stenographer	12.50
The H. & W. B. Drew Co., supplies	5.00
March, 1909.	
E. H. Sellards, State Geologist, traveling expenses, March	81.44
E. H. Sellards, salary for the quarter ending March 31, 1909	625.00
R. M. Harper, Assistant, traveling expenses ($2.25), salary (half month, $50.00)	52.25
Herman Gunter, Assistant, traveling expenses ($12.71), salary ($75)	87.71
John McDougal, Postmaster, postage	10.00
April, 1909.	
E. H. Sellards, State Geologist, traveling expenses, April	46.90
R. M. Harper, Assistant, traveling expenses ($60.05), salary ($70).	130.05
Herman Gunter, Assistant, traveling expenses ($67.35), salary ($75)	142.35
May, 1909.	
E. H. Sellards, State Geologist, traveling expenses, May, 1909	70.25
R. M. Harper, Assistant, salary ($100), traveling expenses ($56.35)	156.35
H. Gunter, Assistant, salary, May, 1909	75.00
Carried forward	$6,605.95

Brought forward	$6,605.95
Keuffel, Esser & Company, one Abney level	13.93
H. & W. B. Drew Company, supplies	32.56
Alpha Photo Engraving Company, engravings	28.90
American Journal of Science, subscription for 1909	6.00
June, 1909.	
E. H. Sellards, State Geologist, salary for the quarter, ending June 30, 1909	625.00
R. M. Harper, Assistant, salary ($100), traveling expenses (33.04).	133.04
H. Gunter, Assistant, salary ($75.00)	75.00
E. H. Sellards, State Geologist, traveling expenses	45.15
Maurice Joyce Engraving Co., engravings	19.17
Ware Bros. Co., publications	6.00
Hill Publishing Co., publications	10.00
Economic Publishing Co., Economic Geology	3.00
The Macmillan Co., publications	8.52
The University of Chicago Press, Journal of Geology	3.00
Frances J. Bulask, publications	2.00
Total expenditures	$7,617.22
Overcharge	117.22
	$7,500.00

A PRELIMINARY REPORT ON THE GEOLOGY OF FLORIDA

WITH SPECIAL REFERENCE TO THE STRATIGRAPHY

BY GEORGE CHARLTON MATSON AND FREDERICK G. CLAPP.

INCLUDING A CHAPTER ON THE

TOPOGRAPHY AND GEOLOGY OF SOUTHERN FLORIDA

BY SAMUEL SANFORD.

PREPARED IN COOPERATION BETWEEN THE UNITED STATES GEOLOGICAL
SURVEY AND THE FLORIDA STATE GEOLOGICAL SURVEY, UNDER
THE DIRECTION OF THOMAS WAYLAND VAUGHAN.

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
WASHINGTON.

OFFICE OF THE DIRECTOR.

Dr. E. H. Sellards, State Geologist of Florida,
Geological Survey of Florida, Tallahassee, Florida.

Dear Sir: I herewith transmit the manuscript and illustrations of a Preliminary Report on the Geology of Florida, with especial reference to the Stratigraphy. By George Charlton Matson and Frederick G. Clapp. Including a chapter on the Topography and Geology of Southern Florida. By Samuel Sanford. Prepared in cooperation between the United States Geological Survey and the Florida State Geological Survey, under the direction of Thomas Wayland Vaughan.

This report has been prepared in accordance with the agreement entered into by the Florida State Geological Survey and the United States Geological Survey on the first day of August, 1907, and is transmitted to you for publication by the Florida State Geological Survey.

Very respectfully yours,

GEO. OTIS SMITH,
DIRECTOR.

A PRELIMINARY REPORT OF THE GEOLOGY OF FLORIDA

WITH SPECIAL REFERENCE TO THE STRATIGRAPHY

GEORGE CHARLTON MATSON AND FREDERICK G. CLAPP.

INTRODUCTION.

OBJECT AND SCOPE OF REPORT.

Previous Information Regarding the State:—Although Florida was settled early in the history of colonization, various natural causes have cooperated to retard the development of the State's resources. At the present time Florida contains the largest unsettled area in the eastern part of the United States.

Various papers containing information relating to the geology of the State have appeared in scientific journals at intervals, especially during the last twenty years of the nineteenth century.[1] Such institutions as the Wagner Free Institute of Science of Philadelphia have published the results of extensive investigations, and the U. S. Geological Survey has at various times sent parties into the State. Numerous scientists, attracted to the South by the delightful climate during the winter months, have attempted, with varying degrees of success, to solve some of the geologic problems; but prior to 1907 no State Geological Survey had been authorized by the legislature and no stratigraphic report, published by the State, of a popular and comprehensive nature has appeared. A prominent object of the present report is to fulfill this important task.

Insufficiency of Knowledge:—It is a fact that, in many States, the geologic conditions are so complicated and diverse that few persons other than geologists and parties engaged in prospecting or developing the mineral resources have even a fair idea of the character, sequence, and significance of the strata, and this is true particularly in Florida. Indeed, this characteristic is more striking in Florida than in many other States, because the greater part of the State is low, and the older geological formations are obscured by a thick mantle of sand. An incorrect belief, still held by many, and unfortunately taught until recently, is that the Florida peninsula is entirely a coral formation. Few people who have not made the subject a study realize that the geologic formations and structure in Florida are in reality very diversified. It is to throw some light on these that the present report is published. An effort has been made to bring together information relating to the geology of Florida and to supplement the knowledge already available with such observations as were possible in the time allotted to the work. However, this report is to be regarded as preliminary, and it is expected that further work will not only add new facts, but will also lead to some revision and modification of the views now held. In the body of the report several unsolved problems are indicated, but it should be borne in mind that not all of them are enumerated.

---

[1] For a bibliography of the geology of Florida see First Annual Report, E. H. Sellards, 1908.

Sources of Information:—As is usually true of reports covering large areas, the data incorporated here are derived from many different sources. All previous literature has been carefully studied and the different views compared and brought up to date, giving credit to the respective investigators. Particularly helpful has been the work of Dr. W. H. Dall, of the U. S. Geological Survey, who has made extensive investigations of the paleontology of the State, and, in 1892, published a treatise of nearly a hundred pages, incorporated in Bulletin 84, of the U. S. Geological Survey, in which he outlined the stratigraphic geology of the State as well as it could then be done. A later report by Dr. Dall was published in the transactions of the Wagner Free Institute of Science. This publication is primarily paleontologic, but it also contains a résumé of the geology and the stratigraphy of the State. These papers have furnished much valuable information which has been incorporated in this report and is specifically acknowledged elsewhere. The work has been carried on under the immediate supervision of Dr. T. Wayland Vaughan, of the U. S. Geological Survey. In addition to exercising general oversight of the work, Dr. Vaughan has examined and identified the fossils collected during the progress of the investigation. He has very generously placed his own extensive notes—accumulated during a series of years—at the disposal of the writers, and has aided both by advice and assistance in the field and in the office. The investigations of Drs. Dall and Vaughan have been of great value because they have formed a basis for all subsequent work. Other geologists, prominent among whom are Dr. E. A. Smith, Prof. Angelo Heilprin, and Prof. Louis and Dr. Alexander Agassiz, have added much to the knowledge of the geology of Florida.

After the first discovery of phosphate in Florida Mr. George H. Eldridge was sent by the National Survey to make detailed investigations of the deposits of that material. He obtained much valuable data, but, unfortunately, did not live to prepare his final report. His notebooks have been available and were occasionally drawn upon by the writers.

The investigations leading to the present report were enabled primarily through the passage of the act incorporating the new State Survey. At the same time the National Survey was engaged in a comprehensive investigation of the geology of the Atlantic and Gulf Coastal Plain of the United States, and hence cooperation between the two bureaus enabled a more thorough study than could have been carried out in a single season by either bureau alone.

In October, 1907, Mr. Clapp began a field study of the stratigraphy and underground water resources of Florida. In November he was joined by Mr. Matson, and together they remained in the field continuously until May 1, 1908, visiting nearly every town in the State and gathering as many data as time would permit.

Having exhausted the funds available for field expenses, the writers repaired to the office about May 1, 1908. On July 1, 1908, Mr. Clapp resigned from the U. S. Geological Survey, and the work of preparing the manuscript for the report was entrusted to the senior author. The base map which accompanies the report was prepared by the Topographic Branch of the U. S. Geological Survey.

ACKNOWLEDGMENTS.

The interest and cooperation of the people of Florida have rendered this work a pleasure, and the authors wish to make public acknowledgment of the numerous favors and courtesies extended to them while in the field and office. Several persons deserve particular mention, among them being Dr. J. N. MacGonigle, of Miami, and Mr. Goff, J. C. Meredith, Constructing Engineer, Key West Extension, and other officials of the Florida East Coast Railway, for affording opportunity to visit the extension of the railroad during process of construction.

Hon. Frank Clark, of Gainesville, furnished introductions which greatly facilitated the work. Dr. De Witt Webb, of St. Augustine, and Dr. E. S. Crill, of Palatka, have interested themselves in the work. Many well drillers have furnished logs and records which added valuable data to our knowledge of the underground stratigraphy, and it is a pleasure to mention particularly Capt. Alexander Near, of Eau Gallie; Mr. H. C. Haven, of DeLand; Mr. W. D. Holcomb and Mr. Edward Pettigrew, of Manatee; Mr. H. W. Pearce, of Arcadia; Mr. H. Walker, of St. Augustine, and Mr. Wm. E. Hughes, of Charleston, S. C. All these and many others, who can not be mentioned on account of lack of space, have given substantial assistance. Many citizens have interested themselves in acting as guides and in furnishing specimens and samples from wells. The officials of

the Atlantic Coast Line Railroad, the Seaboard Air Line Railway, the Florida East Coast Railway and the Louisville and Nashville Railroad, in Jacksonville, Wilmington, Norfolk and Louisville, have allowed access to their profiles and other records, which gave valuable information for use in the construction of the topographic map of the State.

At the time when the field work for this report was begun Mr. Samuel Sanford was engaged in geologic work for the Florida East Coast Railway. The task of investigating the geology of the Keys and the southern end of the State was entrusted to him. The results of Mr. Sanford's work are incorporated in a subsequent chapter.

TOPOGRAPHY AND DRAINAGE.

General Topographic Features:—While Florida is a region of comparative slight relief, its surface configuration presents considerable diversity, ranging from the nearly level plain in the coastal region and the Everglades to the deeply dissected upland in the northern part of the State, where much of the surface is trenched by steep walled valleys, and the highlands of the peninsula where the surface often consists of a series of more or less rounded depressions separated by narrow divides. The range in altitude varies from sea level along the coast to over 200 feet above tide at various points on the ridge which forms the center of the peninsula and to about 300 feet above the same datum near the northern boundaries of Gadsden, Walton, Santa Rosa and Escambia Counties.

The accompanying topographic map (in pocket) is intended to show the approximate areas of land which lie above and below certain altitudes. The datum plane is mean sea level, and the contour lines show the variations in altitude for each fifty feet. This map embodies the results of the earlier topographic surveys, the river surveys of the U. S. Army engineers, and the various railroad surveys, together with a large number of barometric determinations which were made during the progress of the field work. While the exact location of the contours is sometimes more or less uncertain, it is believed that they are sufficiently accurate to give a good idea of the relative areas of different altitudes, and to present a general plan of the broader topographic features of the State. Owing to the small scale of the map, it was necessary to omit such minor details as sink-holes, valleys of small streams, narrow ridges and small, more or less, isolated elevations. The U. S. Geological Survey has already published detailed maps of certain parts of the peninsula, and to these the reader is referred for local information.[1]

---

[1] Arredondo, Citra, Dunnellon, Ocala, Panasoffkee, Tsala Apopka and Williston sheets.

An examination of the map will show that the southern part of the peninsula, comprising an area about 150 miles long and averaging over 100 miles in width, has an altitude of less than fifty feet above sea level. In addition to this large area, there are narrow strips of lowland along the Atlantic and Gulf coasts. It is also apparent that the valleys of the streams do not rise above the 50-foot contour for a considerable distance from the coast, and in one case—the St. Johns River—the stream is nowhere more than thirty feet above tide.

The uplands of the peninsula and adjacent part of north Florida are separated into two more or less distinct parts by the Ocklawaha River. Beginning southeast of Arcadia, a belt of high land extends northward to Summit, in Marion County. This area, which is very irregular in shape, separates the Kissimmee River drainage from the various streams to the westward. In this upland at Lakeland, Brooksville, and several other points, the surface is known to rise more than 200 feet above sea level.

Another broad irregular upland extends from just north of the Ocklawaha River to the Georgia-Florida line. This area forms the divide between the Atlantic and Gulf drainage basins, and includes a considerable tract which rises above 150 feet. Its narrowest part is along the western boundaries of Clay and Duval Counties where it forms the long north-south divide known as "Trail Ridge." This upland includes Lake City with a altitude of 201 feet above tide and Highland on the "Trail Ridge" with an altitude of 210 feet above the same datum place. Near the Georgia line the upland broadens into the Okefinokee swamp which occupies a large area in Georgia, but extends only a short distance into Florida. The western slope of this highland is cut by the Santa Fe River and its tributaries, while its eastern slope is deeply dissected by the tributaries of the St. Johns and St. Marys Rivers.

Near the State line in the northern and western parts of Florida there is a narrow upland which has been deeply eroded by the various streams which cross it. On its seaward side this highland often descends rather abruptly to the low coastal region. The highest points in this region are near the northern line of the State where considerable areas rise above the 250-foot contour. Notable examples of this upland are seen in Gadsden County and in the counties west of the Choctawhatchee River; and Tallahassee, the capital of the State, with an altitude of about 200 feet above tide, is situated upon a remnant which has been isolated by erosion. East of the Apalachicola River, the railroad stations at Monticello, Midway and Quincy are all reported to be over 200 feet above sea level. West of the Apalachicola River, between Argyle and Holt, on the Louisville and Nashville Railroad, and at various points on the Yellow River Railroad, the profiles show that there are considerable tracts of land which rise above the 200-foot contour, while Argyle, De Funiak Springs and Mossyhead are all above 250 feet—the last named being 264 feet above tide. It appears probable that at some localities near the Alabama line the surface may rise somewhat higher and small areas may exceed 300 feet.

Rivers:—The drainage history of Florida has been somewhat complex, and the changes in relative positions of land and sea which have affected the stream are so closely interwoven with the general geologic and physiographic history that their full discussion is left for a subsequent report. At this time it is only necessary to note the general character of the streams and state briefly the factors which have produced the existing conditions. Some of the rivers are confined to the coastal lowlands where they assumed their courses in consequence of the initial slope of the land as it emerged from beneath the sea, and they are therefore known as *consequent* streams. Their positions are dependent upon the original slope of the surficial sand, and their channels are frequently winding. Wherever there were depressions in the sands, lakes were formed and some of the consequent streams consist of a chain of such lakes joined by more or less well defined channels. To this class belongs the Kissimmee-Caloosahatchee system with its numerous lakes.

Wherever the consequent streams have removed the thin mantle of surficial sand and cut into the older formations they belong to the class known as *superimposed* streams. Thus the Caloosahatchee River, which in parts of its course has eroded a channel through the surface formations and into the underlying Pliocene and possibly Miocene marls, is superimposed upon the older formations. In like manner the St. Johns River north of Sanford has been superimposed upon the Pliocene and probably the Miocene rocks. The Manatee and Aucilla Rivers have in parts of their courses been superimposed upon the Oligocene formations. There are in Florida many other examples of consequent and superimposed streams and many of the rivers such as the St. Johns are in part consequent and in part superimposed.

The rivers which cross both the older and younger geological formations existed before the deposition of the sands which form the surface of the lowlands. At that time they entered the sea at the edge of the present highland belt. Where they cross the highland these streams have broad, deep valleys floored with a deposit of alluvium and are often bordered by prominent bluffs. In their courses across the uplands, they take a direction which was determined by the slope of the surface; but they have usually removed the surficial formations and cut deeply into the older rocks upon which they are superimposed.

As the coastal belt emerged from the sea by successive additions to its landward margin these streams gradually extended their channels across this new land and hence became in part what is commonly known as *extended* streams. On the coastal belt they flow in broad, shallow trenches bordered by low banks of sand, and in some cases they have removed the Pleistocene sand and eroded channels in the underlying limestones and marls. The most important extended streams of the State are the Escambia, Black Water, Yellow, Choctawhatchee, Apalachicola, Ocklocknee, Aucilla, Withlacoochee, Hillsboro, Peace and St. Marys Rivers. With the possible exception of the Escambia River all of these streams are in part superimposed upon the Pliocene or older geological formations.

After the deposition of the younger geological formations and the extension of the streams across the newly emerged land there came a slight submergence which caused a shortening of the streams and permitted the sea water to enter the river channels for a distance of several miles from the coast. In this way the lower parts of the stream valleys have been transformed into estuaries which contain brackish water and are affected by the tides. The length of these estuaries or tidal portions of the rivers varies in the different streams, and even in a single river it may vary with the strength and direction of the wind. Strong on-shore winds raise the height of the water and force the sea water farther up-stream, while off-shore winds have an opposite effect.

Lakes and Swamps:—Although the State of Florida is crossed by many large rivers there are numerous tracts of land which are very imperfectly drained and are occupied by lakes or swamps. The lake region will be more fully discussed on subsequent pages, and it is sufficient to note that lakes are very numerous, some of them being of considerable size. The swamps are of varying size, from a few rods to many miles in diameter. The most notable undrained area is in the southern part of the peninsula where the Everglades and adjacent lowlands form a nearly impenetrable wilderness. In this lowland tract lies Lake Okeechobee, which is one of the largest and most interesting lakes in the South Atlantic States. According to the measurements cited by Sanford the Everglades nowhere rise more than 22.4 feet above sea level, and the surface has such a gentle slope that the water which falls during the rainy season forms broad shallow ponds and marshes which afford excellent opportunity for the growth of saw-grass and other aquatic plants. These plants by their partial decay under water have formed peat and muck deposits several feet in thickness.

The smaller swamps and marshes occur in all parts of the State, but they are especially numerous in the belt of lowland which borders the coast, and they become smaller and less numerous in the highlands which border the north line of the State. In the coastal belt there are many small lakes and ponds, some of them permanent, but most of them lasting only during the rainy season. They seldom exceed two or three feet in depth and appear to occupy shallow depressions in the surface of the sand.

In the central part of the peninsula and in some localities near the northern boundary of the State there are lakes and swamps which appear to be the result either of unequal deposition of the surface sands or of solution of the subjacent limestone and consequent lowering of the surface in the manner described under Caverns. Some of these lakes are shallow and resemble those of the coastal belt, but others are deep basins partially or wholly enclosed by a rim of rock. The smaller swamps often contain considerable deposits of peat or muck.

LAKE REGION.

The lake region occupies a large part of the highland in the central part of the peninsula, but similar topography is to be found in both North and West Florida. The southern boundary of the lake region is not sharply defined and it comprises two more or less distinct areas consisting of the lakes in the elevated portion of the peninsula which usually have rock basins and those of the coastal and southern lowlands which occupy shallow depressions in the sand. While the areas characterized by these two types are more or less distinct, there are many lakes in the highlands which may be due to depressions in the sand and there are small lakes in the lowlands which are known to occupy rock basins. The highland area of the peninsula where rock basins predominate has commonly been known as the Lake Region, and for convenience this meaning is retained.

The Lake Region comprises a type of topography common to all limestone areas which have been sufficiently elevated to permit the formation of large underground streams. The character of the surface is well shown by the Williston topographic sheet of the U. S. Geological Survey. The numerous depressions shown in the accompanying text figure, which is taken from this map, are known as sink-holes and, in order to understand their origin, it is necessary to consider the development of the underground drainage.

Caverns:—This region is underlain, at no great depth, by several hundred feet of porous limestones of Vicksburg age. Where surface water bearing carbonic acid, derived from decaying organic matter, enters this rock, it gradually dissolves the limestone and thus forms underground channels.

A large part of the mineral matter which is thus removed by the underground water is carried to the surface; and, entering the rivers, is transported to the sea. In an earlier report by this Survey,[1] there is an estimate of the amount of solid matter removed in this manner. The quantities given were based upon a consideration of the amount of mineral matter removed in solution in eight of the large springs of the State. These springs emerge from caverns in the underlying limestone and they are fed by the rainfall upon the surrounding area. The percentage of mineral matter in solution was determined by analysis and the volume of flow was estimated. By this method Dr. Sellards estimated that Silver Spring brought to the surface 340 pounds of mineral matter per minute. While the quantity of matter in solution in the water of the other springs varied it was in all cases

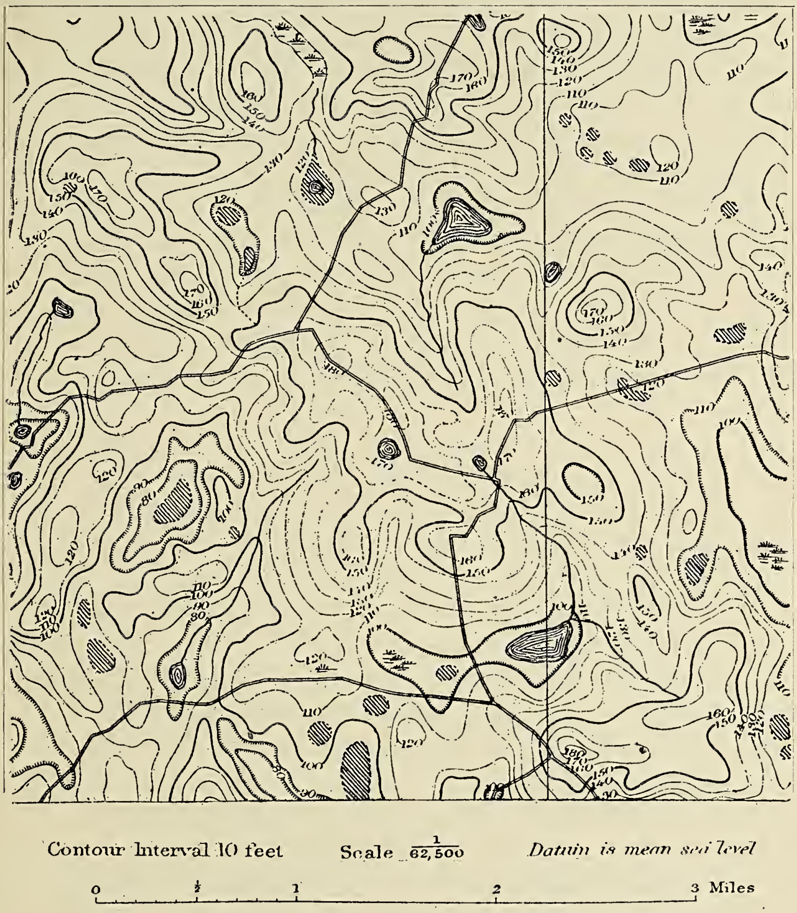


Fig. 1. Map showing sink holes.

---

[1] Sellards, E. H., A Preliminary Report on the Underground Water Supply of Central Florida, Fla. State Geol. Survey, Bull. 1, 1908, pp. 47-48.

large. With a conservative estimate of the average mineral content of the spring water (219 parts per million) and the assumption that about one-half[1] the rainfall of Florida entered the earth and removed this amount of material, Dr. Sellards reached the conclusion that the rate of solution was sufficient to remove, in the limestone section of Florida, about 400 tons per square mile annually. If evenly distributed, this would lower the surface of the limestone about one foot in five or six thousand years. The concentration of this solution along certain beds or channels of active circulation would permit the formation of large underground passages in a comparatively short period of geological time. These channels, known as caverns, are sometimes hundreds of feet in diameter and several miles in length. A level surface and a porous soil favor the development of caverns because most of the rainfall sinks into the earth instead of flowing off over the surface. In the past the region under discussion appears to have furnished an excellent opportunity for the formation of caverns because its surface was comparatively level and covered by a mantle of porous material.

Sink Holes: — As solution progressed the cavern roofs became weakened at various points and collapsed, forming the depressions known as sink-holes. In some areas these depressions are so numerous that they occupy a large part of the surface and give the region its characteristic topography. Splendid examples of ancient sinks such as the Devil's Mill Hopper are to be found in various parts of the State, and instances where sinks have been formed by the collapse of cavern roofs within the memory of persons now living are known in different parts of the Lake Region. A good example of a recently formed sink is to be seen on the road between High Springs and the "Sink" of the Santa Fe River. In the phosphate region a large quantity of water, which has been used in mining operations, is allowed to enter the ground. That this water frequently has a noticeable effect in weakening the roofs of the underground drainage channels is shown by the following quotation from the unpublished notes of Geo. H. Eldridge:

> Sinks have frequently been formed since the mining of phosphate has been undertaken in the vicinities of the settling ponds, or in the line of drainage from the mine washers. The writer has passed over an apparently solid road in the morning to return at night to find in his way a chasm fully 40 feet across, earth, shrubs and trees engulfed, and with the water pouring down to an underground passage in the weirdest way. Again, at one of the Southampton mines, the floor of the old pit, together with an adjoining area of the sand overburden, has sunk several feet with a rift in the earth 4 or 5 feet across in which is shown on the one side the smooth walls of lime spires and connecting ridge; on the

---

[1] Ibid. p. 16.

other the materials that slipped away, no longer being able to retain their purchase on the walls, their support below having been removed.

If the bottom of the sink does not contain an opening, the water which accumulates after a rainfall will usually escape to the underground stream by seepage; but where the amount of rainfall is too great to be carried away in this manner, lakes or ponds accumulate. The level of the standing water in such cases fluctuates, rising after each rainfall and gradually sinking during dry weather. There are hundreds of lakes in Florida which appear to belong to this class. Some of the sinks have an opening in the bottom which connects directly with the underground stream. Into these openings the surface streams plunge, carrying their loads of sediment and other debris. This sediment probably aids the underground stream in enlarging its channel by mechanical wear, but sometimes it accumulates in such quantities as partially or even wholly to close the passage. In such cases the surface water remains in the sink to form a lake. Examples of open sinks receiving the discharge of surface streams are common, conspicuous among them being the sink of the Santa Fe River, the sink of the Chipola River, the Lake sink in Jefferson County and Alachua sink near Gainesville. Alachua sink is important because it illustrates some of the changes through which sinkholes may pass. This sink receives the drainage of a large stream which crosses a prairie (Payne's Prairie). In the early history of the State this region appears to have been in about the same condition as it is today.[1] Later, owing to the outlet becoming closed,[2] perhaps by logs and other rubbish thrown into the stream, a large lake formed in the depression. About 1891, the sink reopened and the basin was drained, effectually ending the steamboat traffic which had developed on the lake.

In some parts of the caverns the water which enters through the openings in the limestone evaporates, leaving a deposit of calcium carbonate. By gradual accretion these deposits may form large pendants—stalactites—hanging from the roof or walls. When the water falls to the floor of the cavern and evaporates, it often forms projections known as stalagmites. The deposits in caverns are frequently highly ornamental and form the chief attraction for visitors.

Sometimes the underground streams form new passages and abandon portions of their old channels. The abandoned channels are the caverns which are visited by travelers. In Florida, only a few caverns have been explored and none are reported to be highly ornamented. The most important caverns which were noted during the field work are located near Marianna, Ocala and Alachua. The one near Alachua is known as Warren cave and is said to be well worth visiting.

---

[1] Bartram, William, Travels, 1791, pp. 187 et seq.

[2] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey Bull. 84, 1892, pp. 94-96.

Natural Bridges:—Where the underground stream emerges it forms a spring and as the roof of the cavern falls it leaves an open channel through which the spring drains to some surface stream. By a continuation of this process the underground stream is transformed into a surface stream. Where a segment of the roof of the underground channel remains after the parts above and below have fallen, a natural bridge results. In Florida natural bridges may also be formed in another manner. In text figure 2 A D represents a longitudinal section of a surface stream flowing toward D and having for its bed the limestone A B C D. A passage, X Y, formed by solution, may permit some of the river water to take a course through the underlying limestone. As this channel is gradually enlarged by solution and mechanical wear, more river water passes through it. Finally, the surface channel may be unoccupied except during high water, or if the underground passage is large enough the surface channel may be entirely abandoned. A surface channel may also be produced across a natural bridge whenever the underground passage is partially obstructed.

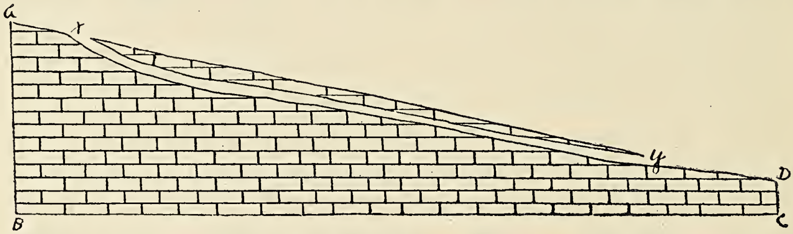


Fig. 2. A D represents the bed of a stream flowing across limestone. The development of an underground channel from X to Y caused the stream to abandon its surface channel.

There are many natural bridges in Florida, small ones being reported near Homosassa, north of Clarksville, in northern Walton County, and in many other localities. Large natural bridges occur on the Chipola River above Marianna, on the St. Marks River, southeast of Tallahassee, on the Santa Fe River, northeast of High Springs,[1] and on several other rivers. The natural bridge on the Chipola River is submerged during high water, and a broad shallow surface channel which crosses the one near High Springs is said to carry a portion of the flood waters of the Santa Fe River. The breadth of the surface channel near High Springs suggests that the natural bridge of the Santa Fe River may have been formed by the second method outlined above. The natural bridge of the Chipola River was submerged at the time the field work was done in that vicinity, so that no observations could be made. However, the broad valley of the river above the bridge indicates that the upper part of the Chipola River has been a surface stream for a long period. Since natural bridges in such rocks are not apt to endure for long periods it appears probable that this one may also have been formed by the second method.

---

[1] See Fig. 1, Plate viii.

Sand Dunes:—A large part of the surface of Florida is covered by a few feet of Pleistocene sand. In the Lake Region this sand has sometimes reduced the original inequalities of the surface. In other cases the formation of sand dunes and ridges has increased the topographic irregularities. However, the dunes and ridges are seldom more than a few feet in height, and hence their effect on the topography is not very marked.

Springs: — The great development of underground drainage in many parts of the State has already been mentioned. Where the streams emerge from their subterranean channels they form springs. It is impossible to make any exact estimate of the number of springs in the State, and it is perhaps sufficient to say that they are exceedingly numerous. They vary in size from mere seeps to springs which give rise to creeks and rivers large enough to float good-sized passenger and freight steamers. The best known and largest of these springs is the Silver Spring in Marion County, which gives rise to a large stream of remarkable clearness and beauty. The water emerges from the basin which probably attains a depth of at least thirty-five feet, and the stream, Silver Spring Run, that flows from this basin, has an average width of about fifty feet and a minimum depth in the center of the channel of more than nine feet. The water is so clear that it is possible to discern objects lying on the bottom and to observe the fish and other aquatic animals. Among the other large springs of the region are Wekiva Spring, in Orange County, the source of the river of the same name; Sulphur Spring, near Tampa; Suwanee Sulphur Spring, White Sulphur Spring, Blue Spring, near Juliette Station; Blue Spring, near Orange City Junction; Green Cove Spring, on the St. Johns; Wakulla Spring, near Tallahassee; Itchetucknee Spring, near Fort White; Poe Spring near High Springs; Crystal River Springs which give rise to the Crystal River; Weekiwachee Spring, near Bayport, and Newland Spring, near Falmouth. All of these springs are well known and many of them are very large. They are supplied with water by the underlying limestone which is everywhere so porous and cavernous that it yields large supplies.

A spring at Tarpon Springs is worthy of special mention because it appears to be in part supplied with water from a small lake. The water emerges at the bottom of the bay a few feet below mean tide level. On the opposite side of the town is a small lake with no surface outlet and apparently occupying a sinkhole. Usually the flow of this spring is comparatively insignificant, but at times the discharge is enormous. Observations made upon the lake just before and after one of these outbursts of the spring appear to show that the lake discharges water into the spring through some underground channel, for the surface of the lake is said to have been lowered several inches while the spring was flowing rapidly.

Aside from the large springs mentioned above there are many others which yield quantities of water, and springs of moderate size are to be found in nearly all parts of the State. Some of the smaller springs are supplied with water from the superficial sands, but many of them derive their supplies from the limestones.

NORTH AND WEST FLORIDA.

In West Florida and in parts of peninsular and northern Florida, the surface configuration has been largely determined by the erosion of surface streams. However, sink-hole topography is common as far west as Walton County, and many of the depressions are occupied by small lakes.

Erosion Features: — From Leon County westward the major streams cross the upland in wide level-floored valleys bordered by well-defined bluffs. The depth of these valleys is due to the erosive action and the width to the meandering of the streams. The valleys usually contain a deposit of sand and mud, which rises but little above the level of the streams and is partially overflowed when the rivers are high.

The small streams of the uplands flow in narrow valleys having steep walls and high gradients. In most cases erosion has not extended far from the main streams, and hence there are many comparatively level areas which form the divides between the principal rivers. On approaching the rivers, the areas of level land become smaller and the number and depth of the valleys increase until the surface is largely reduced to steep slopes. It is also worthy of note that the amount of dissection which the upland has suffered increases toward the south. Thus the largest level tracts of upland are usually found near the northern line of the State. At its southern edge, the upland sometimes descends abruptly to the coastal belt which borders the Gulf of Mexico. In some cases, however, the transition to the coastal lowlands is by a gradual slope.

Lakes:—The uplands are usually covered by a few feet of white Pleistocene sand which masks the minor inequalities of the erosion topography. Moreover, it is frequently difficult to determine whether shallow depressions are sink-holes or are merely due to irregularities in the surface of the sand. However, in the case of such deep depressions as the lake at De Funiak Springs, the sink-hole origin of the basin appears to be unquestionable.

Sand Dunes: — Sand dunes and ridges are common, especially along the southern edge of the uplands, but they are seldom more than a few feet in height. Wind blown sands are probably much more widespread than is indicated by the surface topography. However, at the present time, the heavy precipitation, together with abundant vegetation, prevents the development of an extensive dune topography.

COASTAL REGION.

Streams and Ponds:—The coastal region of Florida comprises a belt of lowland which seldom rises above the 50-foot contour, and over large areas its surface is only a few feet above high tide. Its emergence from the sea took place after the drainage of the uplands had been well developed, and the rivers gradually extended their channels across it as new areas were added to the land. The Pleistocene sand which forms a large part of the surface has a gentle slope toward the sea and is occasionally crossed by small streams which flow in shallow valleys. Minor irregularities in the surface of the sand have given rise to shallow lakes and ponds which cover large areas during the rainy season. The difference in elevation between the bottoms of some of these ponds and the surrounding areas is frequently less than two feet.

Ridges:—Scattered throughout the coastal region are small areas of higher land which in some places resemble sand ridges and in other places are very irregular in shape. In some places they are found to contain a core of rock which is covered by a thin mantle of sand, but frequently they appear to be entirely composed of sand. These areas represent the higher parts of the original sea floor, and their position was determined by the inequalities in the surface of the underlying rock or by unequal deposition of the sands.

Terraces: — In the valley of the St. Johns River and at various points along the coast, the sands form a well defined terrace which rises twenty to thirty feet above tide. This terrace was observed at several localities and it appears to be the result of wave action during the Pleistocene. Similar terraces occur along the other streams of Florida and there is some evidence that there are others at higher levels; but their satisfactory discrimination will require a more detailed study than could be made in the time allotted to the field work.

SHORE LINES.

The State of Florida has an extensive coast line, presenting a great variety of topographic forms. The various agents which have been important in producing the coastal forms are: the waves, the tides, the shore currents, and the growth of organisms, chiefly corals. The configuration of the shore lines is dependent upon the relative importance of these agents.

Coral Reefs:—The coral reefs are restricted to an area near the southern end of the peninsula; and it was to this area that much of the earlier geological work was devoted. In a subsequent chapter Mr. Samuel Sanford will discuss the formation of the keys and the adjacent portion of the mainland in the light of his recent studies in that region. At present it is only necessary to call attention to the fact that coral reefs have been of minor importance in the development of the peninsula of Florida; in fact, there appears to be no reason to suppose that reefs have existed on the west coast or north of the north line of Palm Beach County on the east coast.

Submerged Continental Border:—Reference to the charts of the U. S. Coast and Geodetic Survey shows that the depth of the water along the Florida coast is seldom more than a few feet. As the distance from the land increases, the water gradually deepens over this submerged continental border and there is an abrupt descent to deep sea bottom at a considerable distance from the land. This marginal shelf is to be regarded as a part of the continent now covered by the sea, and it has probably been in part, if not wholly, above water during some period of geological history.

Bars:—In the shallow water at some distance from the shore, the waves gradually build bars which rise nearly to the surface of the water. The material for the construction of these bars is derived from the sea bottom, and hence they vary with the character of the shore. At the present time the prevailing materials on both the east and west coasts is sand, though there is often a considerable admixture of shells. For this reason the bars which are now forming consist largely of sand with a small proportion of shell fragments. In comparatively recent geologic time the beach materials on some parts of the coast appear to have been largely shells and these were built into bars which were afterward cemented to form coquina. Occasional layers of sand and a considerable percentage of silica in the coquina show that terrigenous material was never entirely absent, though it was often of minor importance. In the shallow water along the exposed shores, either of the mainland or islands, currents are formed which transport the beach materials and build them into a variety of forms. One of the common types to be found on the Florida coast is the bar which is built across the entrance to a bay. Such bars are to be found at the entrance of all the bays, and their removal is one of the important problems which confronts the army engineers in their endeavor to make the rivers and harbors accessible to shipping.

On the east coast where the prevailing currents move southward, the bars are commonly extended by additions to their southern ends. On the Gulf coast of the peninsula the dominant currents appear to be in the opposite direction and the bars are usually built by extensive additions to their northern ends. The dominant current on the coast of West Florida appears to move toward the west, though an eastward current of some importance may be inferred from the position of the bar at the entrance to St. Andrews Bay. Bars of the kind described above are to be seen along the entire coast of Florida wherever there are large bays.

Sounds: — Behind the shore bars on the east coast are narrow bodies of shallow water which are commonly known as rivers, though they might more appropriately be termed sounds. To this class belong such bodies of water as the Halifax and Indian Rivers. As the sounds become more nearly surrounded by the growing bars they are changed into lagoons which are in turn gradually filled with silt and thus transformed into marshes. Mosquito lagoon and Lake Worth on the east coast are excellent examples of lagoons, and there are numerous marshes along both the east and west coasts.

About twenty years ago an attempt was made to open a passage for steamship navigation by deepening the sounds and lagoons. This plan was successful, but in recent years the channels have been allowed to become obstructed by sand bars and oyster reefs. In the last few years interest in this "inside" channel has been revived, and it is now proposed to extend the passage northward to New Jersey.

Inlets: — Where drainage from the land enters a sound or partially enclosed bay, the water escapes through a narrow passage in the bar known as an inlet. As the bars are built under the influence of a prevailing current, the inlet is gradually shifted in the direction of growth. After a time the opening becomes so obstructed that a new inlet is formed by the action of high water. Usually the inlets are formed near the head of the bar and their direction of movement on the Atlantic coast is southward and on the Gulf coast northward or westward. At Jupiter on the east coast an opening is sometimes dredged near the north end of the bar and this opening is gradually shifted toward the south. It has been found that the inlet remains open much longer when the opening is made toward the northern end of the bar than when it is located farther south.

Tidal Runways:—At ordinary high tide the level of the water in the bays and sounds is raised from one to two feet above the normal low water level. If, at the same time, a strong wind is blowing toward the land the water rises much higher. When the tide recedes, a seaward current is formed which scours the bottom and sides of the channels. Frequently the water pours through some low gap in a shore bar, thus helping to form a passage. Many of the inlets across the Florida bars are formed in this way. To the erosive action described above, Mr. F. P. Gulliver[1] has given the name of "tidal scour," and he thinks that the channels near Cedar Keys present an example of tidal runways produced by tidal scour, and he designates these runways as the "Western Florida Type." At the mouth of the St. Johns River and elsewhere along the South Atlantic and Gulf coasts the army engineers have constructed dams to narrow the runway so that the effect of the tidal scour will keep open a channel deep enough to permit the entrance of large vessels. Examples of tidal scour along the keys and the southern part of the Florida peninsula will be discussed by Mr. Sanford.

Capes:—Many of the important capes of Florida appear to have been built of sand deposited by the currents moving along the shore. Cape Canaveral on the east coast was formed where the easterly trend of the coast caused the southward moving current to move outward from the coast into the deeper water which checked its velocity and caused it to deposit some of its load of sand. From the outward end of the cape there projects a long, narrow spit of sand which rises nearly to the surface of the water. The seaward end of the spit is often bent into a hook by the action of the current.

On the west coast the northward moving current encounters the islands near the west end of St. Vincent Sound, and turning westward forms Cape San Blas. Cape St. George at the western end of the island of the same name, and Southwest Cape, west of Apalachee Bay, appear to have been formed in a similar manner. All of these capes are gradually being extended seaward by the continual addition of more material transported along shore by the currents. In addition to the capes mentioned above, there are many minor projections usually known as points, which originated in practically the same manner as the larger capes. In 1898 Dr. F. P. Gulliver[2] studied the origin of Capes Canaveral and San Blas and designated them "current cuspate forelands."

---

[1] Shoreline topography, Proc. Amer. Acad. of Arts and Sciences, Vol. 24.

[2] Gulliver, F. P. Shoreline topography. Proc. Am. Acad. of Arts and Sciences, vol. 24, pp. 180-181.

SOILS.

ORIGIN.

The soils of Florida are almost all based upon the sandy formations of Pliocene and Pleistocene age; and, since the gray Pleistocene sand is the most widespread of the surface deposits, it naturally forms the soils over the greater portion of the State. The Lafayette soils occupy considerable areas in northern and western Florida and they often form the subsoil where the Pleistocene sands are thin. The Alachua clay and the Pleistocene marls are so thinly covered in some parts of Peninsular and West Florida that they form a part of the subsoil. In some areas, where erosion has been especially active both Pliocene and Pleistocene deposits have been removed, leaving the older geological formation exposed to form the soils; but such areas are of limited extent, and are comparatively unimportant. In a few localities residual materials formed by the weathering of the Oligocene formations lie so near the surface that they form a more or less important part of the soil or subsoil.

Other types of soil occupy a large area in the southern part of the peninsula and smaller areas in various other parts of the State. These are the peat and muck soils which have their greatest development in the Everglades, but are found in many other localities where swamps exist. They consist of organic matter mixed with more or less inorganic material, such as sand and clay. These soils are of recent origin and are still being formed, especially over a large area south of Lake Okeechobee where the surface is very low and flat and the drainage imperfect.

The Pleistocene sands form the soil in nearly all of peninsular Florida and extend over a part of the uplands in northern and western Florida. Their occurrence in detail may be gathered from the description of the distribution of the Pleistocene formations. The soils of the Lafayette formation are largely confined to the upland areas near the northern boundary of the State. They do not form large, unbroken tracts, but occur in more or less isolated areas where the post-Pliocene sands are absent. In many localities the overlying sands are so thin that the Lafayette deposits form an essential part of either the soil or the subsoil, even where the surface materials are younger. This is the condition in a part of the important tobacco producing area in Gadsden County.

Pleistocene marls and coquina, in a more or less decomposed state, form the subsoil at various places along the east coast and along the west coast south of Bradentown. These marl and coquina beds are discussed under the head of geology, and their distribution, so far as it is now known, is given. However, it should be remembered that the areas where these Pleistocene beds lie near enough to be considered part of the soil are much more restricted than is their geological distribution.

In the central part of the peninsula, especially northwest of Gainesville, the Alachua clay is so near the surface that it forms a part of the subsoil, but does not enter into the formation of the surface soil. Over much of the area where this formation occurs, it is too deeply buried to be considered a part of the soil.

On the north bank of the Manatee River, in the vicinity of Ellenton, there are some areas of land, valuable for truck gardening, where the residual clays left by the solution of the limestone of the Tampa formation form very good soils. In some places, these clays contain more or less Pleistocene sand, and angular or sub-angular fragments of flint are common. There are doubtless other localities where the residual products of this limestone are near enough to the surface to form part of the soils, but their distribution is not yet known. The limestones of the Chattahoochee formation and the Vicksburg group may form parts of the soils in a few localities, but they are usually too deeply buried beneath the younger geological formations to be important in soil formation. It is the proximity to the surface of marls or residual products of the Vicksburg group which is regarded as the source of the fertility of many of the "hammock" lands near the west coast. It is doubtless the presence of such materials near the surface which accounts for the excellent growth of timber in places where the surface soil is very poor.

CLASSIFICATION.

In 1897, Prof. Milton Whitney made a general examination of the Florida soils and classified them as follows:

> The principal types of soils examined were the first, second and third quality of high pine land; the pine flats or so-called "flat woods"; the light hammock, the gray or heavy hammock, the mixed land, the heavy marl hammock; the pineapple land; the Etonia scrub, the spruce-pine scrub; and the Lafayette formation.

Since the publication of Prof. Whitney's report detailed soil surveys have been made in the vicinity of Gainesville, and in Jefferson, Leon, Gadsden and Escambia Counties. In the detailed work, the soils were classified by their physical properties, origin and topography. In this classification texture is the most important characteristic. In Florida, the principal types of soils recognized are sands, fine sands, sandy loam, and fine sandy loams. Subordinate types are loams, silt loams, clays, muck and meadow. These types have, with some exceptions, been grouped into three series and correlated with similar soils elsewhere in the coastal plain. Since a detailed description of the soils cannot be given in this report, no attempt will be made to discuss the various series represented in the State. Aside from the general types of soils which have been grouped into series and correlated with similar soils outside of the State, there are the Gainesville sand, the Gadsden sand[1] and some other types which have not yet been correlated.

The clay and loam soils of Florida cover a very limited area, and are not of great importance. The clay soils are largely restricted to small tracts in the neighborhood of streams and are not tilled. In this connection, it should be borne in mind that much of what is commonly called clay in northern and western Florida is to be classified as a sandy loam, because, while it is more or less plastic, sand is the most important constituent. The greater part of Florida has either a sandy or sandy loam soil, and while these soils may be subdivided into a large number of types, they possess, as a whole, certain general characteristics. When brought under cultivation, they commonly have a low natural productivity, but they respond quickly to proper treatment, and can be made to produce large crops which grow rapidly and mature early. These characteristics, when linked with a subtropical climate, make the production of early fruits and vegetables very profitable. In order to procure the best results, it is necessary to exercise skill and judgment in the treatment of the soils, and, in some instances, considerable money must be expended for fertilizers. There is apt to be a deficiency of moisture on some of the sands and sandy loams, and hence irrigation is sometimes practiced.

Fertilizers are used in nearly all parts of the State, the amount and kind of fertilizer required in the different localities being governed by the nature of the crops grown and the experience of the most successful farmers. A striking example of the productivity of a sandy soil properly tilled is furnished by the yield of pineapples which are grown upon the ridge of sand near Fort Pierce. The value of barnyard refuse and legumes as fertilizers is recognized in some localities, but their use should be much more extensive. Some recent experiments of the Department of Agriculture[2] are of interest, since they show that lime, which is not generally used on Florida soils, may add greatly to the productiveness of certain types of the sand and sandy loam soils.

---

[1] Names applied by Bureau of Soils, of the Department of Agriculture, to certain soils in this region; not geologic subdivision. Soil survey of the Gainesville area, Florida; soil survey of Gadsden county, Florida, U. S. Dept. Agriculture Field Operations Bureau of Soils, 1904, pp. 269-286.

[2] Soil survey of Escambia county, Florida, Field Operations of the Bureau of Soils, U. S. Department of Agriculture, 1906, pp. 348. See also "Soil Studies" by the Florida State Experiment Station, Bulletins 87 and 93.

The peat and muck soils of Florida have not been extensively used because they are in swampy areas which require drainage. Extensive drainage operations are in progress in the Everglades, and, if these are continued, large areas of peat soil will be available for cultivation. The natural productivity of the peat and muck soils of Florida has seldom been determined, but, judging from the experience of farmers in other States, it is safe to predict that the Everglade soils are destined to take rank among the best lands of the State for the production of certain crops. Moreover, experience in several other States has shown that such soils seldom require the addition of complete fertilizers such as are used on sandy soils. In fact, the addition of small quantities of salts of potassium should usually be sufficient to cause a peat or muck soil to produce good crops, though possibly, in some cases, the addition of phosphates would be necessary. These facts are important because it will cost much less to fertilize the peat and muck soils than is now being expended on the sandy soils.

STRUCTURE.

One of earliest discussions of the structure of Florida was written by Johnson,[1] in 1888. Though he was hampered by lack of detailed knowledge of the stratigraphy of the State, Johnson presented considerable evidence to show that the peninsula is a broad anticline. The conclusion reached by him was, in a general way, the same as that of several subsequent writers. His paper is accompanied by a section of the strata across the northern end of the peninsula showing a broad arch with the apex in the vicinity of Gainesville. The location of the crest of the arch was recognized by the sink-hole topography which was thought to indicate the presence of "Eocene" limestone (Oligocene, Vicksburg group) within less than 100 feet of the surface, and the dips away from the central part of the peninsula were determined by noting the presence of younger formations at the surface and by the altitude of the Oligocene beds in wells at various points.

About two years after the appearance of Johnson's paper, Prof. Shaler[2] published a brief discussion of the topography of Florida, and in the same article stated his ideas of the structure of the State. Prof. Shaler appears to have regarded the peninsula as a broad arch which he likened to the Cincinnati anticline:

> The first question before us concerns the origin of the Florida uplift. It will be observed that we have in the peninsula of Florida a very remarkable

---

[1] Johnson, L. C., Amer. Jour. Sci., 3d series, Vol. 36, 1888, pp. 230-236.

[2] Shaler, N. S., Topography of Florida, Bull. Mus. Comp. Zool., Vol. 16, No. 7, 1890, pp. 139-156.

ridge, which has grown up from the sea-floor to the altitude of about five thousand feet; and a somewhat similar elevation in the archipelago of the Bahama Islands. Neither of these ridges has a mountainous character. Indeed, it is at first sight difficult to find the analogues of these great anticlinal-like folds in the existing structures of the land. They can hardly be classed with any of our known table-lands, for the reason that such elevations are in all cases more or less associated with definite mountain folding. The only similar structure which is known to me is that exhibited in the "Cincinnati anticlinal," that well-known ridge extending from near Columbus, Ohio, to Northern Alabama. This elevation in length and breadth may be compared to that of Florida, though it never had more than one-half the height of the Floridian peninsula.

It should be remembered that there is to be included with the peninsula the submerged plateau which borders it on either side and extends out to the abysmal depths of the ocean, and when Prof. Shaler speaks of a broad earth arch he includes in it not only the land but this submarine plateau which in places extends over 150 miles beyond the coast and which descends steeply to profound depths. In a later paper, Prof. Shaler[1] reiterates the same view and states that he regards Florida as a broad submarine fold, approximately 600 miles in length which has risen from a depth of about 5,000 feet.

In commenting on the hypothesis advanced by Prof. Shaler, Dr. Dall[2] says:

> In considering the topography of Florida, it has been customary among geologists and others to speak of the "central ridge," "elevated axis," and in the latest contribution to the subject Prof. Shaler regards Florida as "formed of lowlands rising as a broad fold from the deep water on either side to a vast ridge, the top of which is relatively very flat, there being no indication of true mountain folding in any part of the area." In an extremely wide and general sense, it is, of course, true that the peninsula forms a great fold, but in the ordinary and literal meaning of the words this description conveys an inaccurate idea of the structure of the region.

Dr. Dall regards the structure of Florida as characterized by low folds approximately parallel to the general trend of the peninsula. By means of railroad profiles he finds indications of two well defined ridges, one near the Atlantic coast and another near the Gulf coast. A third ridge is noted in the vicinity of Brooksville and Plant City. The eastern ridge which forms the eastern boundary of the central "lake basin" includes the well known Trail Ridge and was thought to be composed of "Miocene" rocks. In this connection "Miocene" is probably intended to include the Oligocene rocks belonging to the Apalachicola group which were then known as Miocene. The western ridge forms the western boundary of the central "lake basin" and passes through Lakeland. The theories advanced by Dall and Johnson differ in one important point. Dall believes that the central lake basin is a synclinal valley; Johnson holds that this region which he designates as "high hammocks" or "lake region" represents the eroded apex of a broad arch.

---

[1] Shaler, N. S., Relation of Mountain Growth to Formation of Continents. Bull. Geol. Soc. Amer., Vol. 5, 1894, pp. 206.

[2] Dall, Wm. H., Neocene of North America, Bull. U. S. Geol. Survey No. 84, 1892, pp. 87.

Considering the State of Florida as a whole, it is merely the southern extension of the coastal plain, and its history has in general been the same. Broadly speaking there are two distinct axes of uplift which appear to extend in a general north-south direction. The outline of the Vicksburgian limestone west of the Apalachicola River indicates a gentle uplift, and field observations show that this limestone has there an altitude of about 75 to 100 feet over a considerable area. From this uplift, the rock dips rapidly to the south and west, and more gently, but still perceptibly, towards the southeast. Towards the north and northeast it rises to form the basis of the highlands of southern Georgia and Alabama, and then gives place to the underlying Jackson, which outcrops farther north. The exact trend of the uplift which brought the Vicksburg to its present altitude in west Florida is not known, but it is probably to the east of north. The peninsular portion of Florida represents a broad uplift such as was postulated by Johnson and Shaler, and the comparison with the Cincinnati arch appears to be quite appropriate. The objection to the use of the term "anticline" in connection with these broad uplifts is due to the fact that most geologists are inclined to associate the word with narrower archings of the strata, such as are common in the Appalachian or other closely folded regions. By the use of the term "arch" it is hoped that this objection will be removed. In the peninsula of Florida, the arching of the beds has raised the lower Oligocene to an altitude of more than 100 feet above tide over considerable areas from the vicinity of Brooksville and Croom northward to and beyond Gainesville, Live Oak and Lake City. Around the outcrops of the rocks belonging to the Vicksburg group which have been exposed on account of the erosion of this arch, are the exposures of the formations which comprise the Apalachicola group and younger beds. The rocks belonging to the Apalachicola group occupy a broad belt from Sarasota northward to the Georgia-Florida line, and extend westward to where they are overlapped by the beds of Miocene age. On the eastern side of the central uplift the Apalachicola group occupies a much narrower area and is soon buried beneath younger beds. Since there is little difference in the thickness of the beds belonging to this group on the east and west sides of the arch, it may be readily inferred that the easterly dips are more steep than the westerly.

The northern end of the arch which forms the peninsula pitches gently downward, so that the limestones of the Vicksburg group dip below the surface north of Live Oak and Lake City and the formations comprising the Apalachicola group appear in the valley of the Suwanee River. The southern end of the arch sinks gently beneath the younger formations so that the limestones of the Vicksburg group lie several hundred feet below the surface in Lee County and at Key West, where they were encountered in drilling wells.

The varying depths to rocks of Oligocene age along the east coast of Florida are probably due, in part, to local variations in the rate of dip and to various minor folds. There appears to be little doubt that any upheaval which produced the broad arch which forms the peninsula of Florida would also produce minor arches or folds parallel to the direction of the main uplift, as well as minor folds transverse to the main arch. The satisfactory discrimination of these minor folds calls for a large amount of detailed stratigraphic work based upon a knowledge of the fossils representing different horizons. It is possible that the ridges mentioned by Dr. Dall are really minor folds, but he does not appear to have eliminated the possibility of their being due to circumdenudation. That there are many minor folds in Florida cannot be denied. Good examples of such folds are those which Dall[1] mentioned on the Caloosahatchee River. These small folds are not more than ten to twelve feet in height and are usually not more than one-quarter of a mile wide. They are of more than usual interest because they involve marls of Pliocene age and hence are probably of Pleistocene or even of Recent age.[2]

---

[1] Dall, Wm. H., Notes on the geology of Florida. Am. Jour. Sci., 3d series, vol. 34, 1887, p. 168.

Dall, Wm. H., Tertiary fauna of Florida. Trans. Wag. Free Inst. of Sci., vol. 3, pt. 6, 1903, p. 1604.

Dall, Wm. H., Neocene of North America, Bull. U. S. Geol. Survey No. 84, 1892, p. 143.

[2] For evidence of minor folds in the Chattahoochee limestone and in the Alum Bluff formation, see paper on "Fuller's Earth Deposits," by E. H. Sellards and Herman Gunter (pp. 277-284).

STRATIGRAPHIC GEOLOGY.

TERTIARY.

OLIGOCENE.

The oldest rocks which have been recognized in Florida belong to the Oligocene series. They may be separated into two divisions, called here the Vicksburg group and the Apalachicola group. These two subdivisions were formerly regarded as Eocene and Miocene, respectively. One of the earliest attempts to fix the age of the rocks of Florida was made by Conrad[1] in 1846. In his paper Conrad referred both the "silex beds" and the limestone of the Tampa formation, together with the prevalent rock of the peninsula, to the upper division of the Eocene. For many years the rocks here included in the Vicksburg group continued to be called Eocene by various writers, including Bailey,[2] Tuomey,[3] Smith,[4] Dall,[5] and others. The deposits here called Apalachicola group were first differentiated from the "Vicksburg" in 1887, when Langdon[6] examined these formations along the Apalachicola River and classified them as probably "Miocene." This name was retained for some time, but it was modified by the use of "Old Miocene" or "Subtropical Miocene" to distinguish it from the later Miocene. In 1896, Dall[7] published a brief statement of the reason for regarding the so-called Eocene and the so-called Old Miocene of Florida as Oligocene. This usage has since prevailed in many, but not in all, of the publications dealing with southern coastal plain geology.

VICKSBURG GROUP.

After the recognition of the "Old Miocene" there remained a considerable thickness of rock which was still regarded as Eocene and

---

[1] Conrad, T. A., Observations on the Geology of a part of East Florida, with a catalogue of recent shells of the coast. Am. Jour. Sci. 2d ser., Vol. 2, 1846, pp. 36-48.

[2] Bailey, Prof. J. W., Am. Jour. Sci., 2d ser., vol. x, 1849, p. 282.

[3] Tuomey, Prof. M., A notice of the Geology of the Florida Keys, Am. Jour. Sci., 2nd ser., vol xi, 1850, pp. 390 et seq.

[4] Smith, E. A., On the geology of Florida, Am. Jour. Sci., 3rd ser., vol xxi, 1881, pp. 292-309.

[5] Dall, Wm. H., Neocene of North America, U. S. Geol. Surv., Bull. 84, 1892, pp. 101-105.

[6] Langdon, Danl. W., Jr., Some Florida Miocene, Am. Jour. Sci., 3rd ser., vol. xxxviii, 1889, pp. 322-324.

[7] Dall, Wm. H. Descriptions of Tertiary fossils from the Antillean region, U. S. Nat. Mus. Proc., vol. xix, No. 1110, 1896, pp. 303-305.

	Period
Quaternary	Recent
	Pleistocene
	Pliocene
Tertiary	Miocene
	Oligocene

TABLE OF GEOLOGIC FORMATIONS IN FLORIDA

	Period	Group	Formation		Lithologic Description of the Formation	Member	Lithologic Description of the Members	Old Names. See Also Text of Report
Quaternary	Recent				Human remains. Vermetus rock. Beach Sands. Coquina. Aeolian deposits. Lacustrine deposits. Chemical deposits. Alluvial deposits.			
	Pleistocene				Yellow sand. "Vermetus rock." Coquina "Planorbis rock" Gray sand. Fossiliferous marls.			
			Palm Beach limestone		Light colored limestone, with sandy beds and loose sand.			"Everglades limestone" included part of Palm Beach limestone Miami oolite, and Lostmans River limestone.
			Miami oolite		Light gray to white oolitic limestone, sandy in places.			
			Key Largo limestone		Coralline limestone; reef rock.			
			Key West oolite		Light gray to white oolitic limestone.			
			Lostmans River limestone		Dark to light hard to friable limestone, sandy or marly in places			
			Unconformity					
Tertiary	Pliocene		Lafayette	Largely contemporaneous deposition	Clay and sand with some pebbles, color usually red or yellow.			Land pebble phosphates—Bone Valley gravel.
			Bone Valley gravel		Light colored gravel and marl, containing phosphatic pebbles.			"Archer beds"—Alachua clays.
			Alachua clay		Greenish sandy clay, weathering yellow or red.			"De Soto beds" represents "Arcadia marl," "Peace Creek bone bed," and Alachua clay.
			Nashua marl		Light colored sandy shell marl.			"Arcadia" marl regarded as a phase of the Caloosahatchee.
			Coloosahatchee marl		Light colored sandy shell marl.			"Floridian group," proposed for Pliocene beds of Atlantic and Gulf States.
			Unconformity (?)					
	Miocene		Jacksonville formation (East Coast)	Contemporaneous deposition	Light gray to white limestone weathering light yellow. Light gray to yellow clay and gray sand. Some chert beds.			
			Choctawhatchee marl (West Florida and St. Johns Valley)		Greenish to light gray sandy shell marl or greenish gray clay.			
			Unconformity					
	Oligocene	Apalachicola Group	Alum Bluff formation		Gray to green sands, clays and fuller's earth. Limestone occurs in some localities but it is usually impure.	Shoal River marl Oak Grove sand Chipola marl	Greenish to gray sands and marls. Very fossiliferous. Light gray sand and marl. Very fossiliferous. Gray to yellow shell marl.	Chipola group and Chipolan stage—Apalachicola group. "Sopchoppy limestone" tentatively included in Alum Bluff formation. "Manatee River marl" included in Alum Bluff formation.
			Chattahoochee formation (West Florida)	Believed to have been deposited contemporaneously	Light yellow to gray earthy and siliceous limestones, sometimes cherty. Sand and clay rare.			"Aspalaga marl" part of Chattahoochee formation.
			Hawthorne formation (Central Florida)		Yellow limestones, often phosphatic. Greenish or reddish sands. Green clays.			"Ocheesee beds"—Chattahoochee formation and may include the upper limestone of the Tampa formation.
			Tampa formation (South Florida)		Yellow limestones and greenish clays. Some chert nodules and layers.			"Waldo formation" (exact position doubtful).
			Unconformity					
		Vicksburg Group	Ocala limestone		Soft, porous, light gray to white limestone with beds of marl and layers of chert.			"Levyville formation"—probably Ocala limestone.
			"Peninsular" limestone (Central Florida)		Soft, porous, light gray to white limestone containing marl beds and layers of chert.			
			Marianna limestone (Western Florida)		Soft, porous, light gray to white limestones containing some marl and more rarely clay beds. Layers of chert common.			

was known as the "Vicksburg limestone."[1] This name[2] had been used to include all the older Tertiary rocks of the peninsula, comprising both the Vicksburg and the deposits here called Apalachicola group; but with the increased knowledge of the geology of the State it was gradually restricted to the older limestones. Subsequent study indicated that this group of older limestones, while presenting but slight lithologic variation, was divisible upon paleontologic grounds into two parts, the lower division (here called "Peninsular") being designated the Vicksburg "limestone" and the upper division being named the Ocala limestone. Still later, Dall[3] proposed the abandonment of the name Vicksburg as applied to limestones of the peninsula of Florida, and the substitution of the term "Peninsular" for the lower division above described. He states:

> From the observations on the typical Vicksburgian by Coloney Casey it seems probable that the Orbitoidal limestone which forms the mass of the Floridian plateau, and which has been, in this work and in the literature generally called the Vicksburg limestone, may really form a different horizon altogether from the typical Vicksburgian and be intermediate between the latter and the nummulitic Ocala limestone. In order to promote clearness and avoid confusion, it is probably advisable to adopt a distinct name for the Orbitoidal phase or formation, for which I would suggest the term Peninsular limestone. This is intended, not as a permanent formation-name, but as a general term for the fundamental plateau limestone of Florida, in which a close and thorough study may result in the discrimination of more than one horizon or zone.

The reason for the change suggested by Dall[4] is the fact that the fossils which have long been regarded as characteristic of the Vicksburg have been found to occur in other horizons, and hence their occurrence in the limestones which underlie the nummulitic rock of the peninsula cannot be regarded as proof of equivalence of that limestone with the limestone at the type locality at Vicksburg, Miss. The question of the correlation of the Florida formations has been further complicated by the fact that there are two horizons represented in the bluff at Vicksburg. To avoid further confusion, however, the Oligocene rocks in Florida which were originally known as the Vicksburg "limestone" are here designated the Vicksburg group. They are thought to comprise three formations, here called the Ocala limestone, the "Peninsular" limestone and the Marianna limestone.

The "Peninsular" and Ocala limestones have already been recognized by Dall. The name Marianna limestone is here given to the soft, porous, light-gray to white limestones of western Florida, which are characterized by an abundance of *Orbitoides mantelli* and other foraminifera associated with many other fossils, prominent among which are *Pecten poulsoni* and *P. perplanus.* At the type locality, (Marianna, Jackson County) this limestone is so soft that it can be cut into blocks with a saw. It contains some beds of chert and many of the fossils are silicified. Lithologically, the rock at Marianna resembles the Ocala limestone at Ocala and the "Peninsular" limestone; but it differs from the former in the character of its fauna, especially in the absence of nummulites, and it is believed that it may represent a horizon below the "Peninsular" limestone of Dall. The close lithologic resemblance between the Marianna limestone and the "Peninsular" limestone, however, makes it possible to combine much of the discussion concerning these two formations.

---

[1] Dall, Wm. H. Neocene of North America, U. S. Geol. Survey, Bull. 84, 1893, pp. 101-104.

[2] Smith, E. A. On the Geology of Florida, Am. Jour. Sci., 3rd ser., vol. xxi, 1881, pp. 292-309.

[3] Wagner Free Inst. of Sci., vol. iii, pt. 6, p. 1554.

[4] Loc. Cit.

MARIANNA AND "PENINSULAR" LIMESTONES.

Stratigraphic Position:—The base of the "Peninsular" limestone is not exposed in Florida and there is no satisfactory evidence that it has been reached in drilling wells; hence the character of the subjacent formation is not known. Reference has already been made to the uncertainty concerning the exact correlation of the "Peninsular" limestone of Florida. It will thus be seen that no satisfactory conclusions can be drawn concerning the relation which the "Peninsular" limestone bears to the underlying beds. The relation of the Peninsular limestone to the overlying formations will be discussed in connection with those formations.

The Marianna limestone is thought to be the stratigraphic equivalent of the upper part of the bluff at Vicksburg, Miss., and some of the wells in west Florida enter beds of sand and clay which probably represent older horizons; but the stratigraphic relation of the formation to these older beds cannot be determined. In west Florida, where this formation is recognized, it is unconformably overlain by beds belonging to the Apalachicola group or by post-Pliocene formations.

Lithologic Character: — The Marianna and "Peninsular" formations consist of soft, porous, white or light-gray limestone, sometimes resembling marl, especially when partially decomposed. Some bands of darker-colored, dense limestone are reported at various localities where these formations have been penetrated by drilling, and nodules and layers of chert are common throughout them, but chert beds are especially prominent in certain horizons. The chert beds are usually darker in color than the limestone and range in thickness from a fraction of an inch to twelve or fifteen feet. In some localities as many as six or seven successive beds of chert have been encountered in a single well. In general, the heavier layers are more persistent; and it is usually the chert which forms a nearly water-tight cap to the artesian water beds in these formations. Certain horizons are abundantly fossiliferous, containing innumerable specimens of Orbitoides and shells of mollusks such as *Pecten poulsoni,* etc. At several localities the rock is so soft that it can be cut into blocks with a saw; and upon exposure to the weather these blocks harden rapidly, making a very fair quality of building stone. Beds of sand, sometimes ten feet or more in thickness, are reported in some of the wells which penetrate this formation. In general, these sands appear to be most numerous in the northwestern part of the State.

Thickness:—The thickness of the "Peninsular" limestone and the Marianna limestone appears to be exceedingly variable. The thickness given by Foerste,[1] from his investigations of the Vicksburgian limestones in southwestern Georgia and the adjacent part of Florida, is 220 feet, and probably this may be regarded as the approximate measure of the thickness of the Marianna. At Salt Mountain, Alabama, the rocks of the Vicksburg group are reported by Dr. Dall[2] to have a thickness of 140 feet, and on the basis of well borings the same writer estimates the thickness to be over 350 feet at Gainesville, 212 feet at Lake Worth, and 1,068 feet at St. Augustine. From recent examinations of well borings by Drs. Vaughan and Bassler, limestone of Vicksburg age is known to have a thickness of over 225 feet at Quincy, 250 feet at Alachua, and 325 feet at Bartow. Apparently there is a marked thickening of these limestones from the exposures of Georgia and Alabama southward. It is hard to tell just how much reliance can be placed on well records, because the drill may penetrate some distance into a formation before characteristic fossils are obtained; and it is possible for fossils to drop from the side of the bore and thus continue to appear in the drillings far below the base of the formation to which they belong. Of all the estimates given above the one at Gainesville is probably the most reliable because the well is cased to the bottom.

Physiographic Expression: — The "Peninsular" and Marianna limestones are characterized by a topography produced by solution with numerous underground streams, natural bridges, sink-holes and large irregular depressions. The underground streams of these formations attain considerable size as is shown by a number of large springs which emerge, apparently from definite channels. The most noted natural bridge of the Marianna limestone is on the Chipola River near Marianna; but there are many of smaller size, both in this formation and in the "Peninsular" limestone. Wherever the limestone rises near the surface, sink-holes characterize the topography, and the sinks form many lake basins in the central part of the peninsula. (See Fig. I, pl. II, p. 58.)

---

[1] Foerste, Aug. F., Am. Jour. Sci., 3rd ser., vol xlviii, 1890, p. 46.

[2] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, p. 103.

Paleontologic Characters:—Both the "Peninsular" limestone and the Marianna limestone are characterized by an abundant fauna, the most prominent fossil being *Orbitoides mantelli,* associated with *Pecten poulsoni* and *P. perplanus.* Dall[1] says that the fauna of the "Peninsular" limestone includes about two hundred and twenty-two species, of which one hundred and two are restricted to it. With the imperfectly known fauna of the Ocala limestone, it has fifteen species in common, while nine species continue into the "silex beds" and limestone of the Tampa formation and two species continue into the Miocene and on down to the recent fauna.

Structure:—The "Peninsular" and Marianna limestones have been affected by the various earth movements which have produced the present structure of the State. The major structural features consist of broad anticlinals, such as are described under the general discussion of the structural features of the State. The dips are low and are generally seaward. Local variations in altitude of the surface of these limestones are so pronounced as to suggest that there has been considerable local warping as well as a general arching. Toward the southern end of the peninsula the "Peninsular" limestone dips southward beneath the Everglades where it is probably buried under hundreds of feet of younger sediments. Along the east coast there are marked variations in depth to this formation; but it probably does not rise within less than about 200 feet of the surface, and at Jacksonville it is not less than about 525 feet from the surface.

At Tampa, on the west coast, the "Peninsular" limestone probably lies somewhat more than 100 feet below the surface, but farther north along the coast it may be exposed. Apparently the dip of the Marianna limestone toward the southwest in the long western extension of the State is very rapid, for at Pensacola this limestone is buried to a depth of more than 1,100 feet beneath younger sediments.

Local Details:—As early as 1849 limestone of Vicksburg age was noted in Florida by J. W. Bailey,[2] who obtained some "Orbitulites" from a chert at Pyles Plantation, about forty miles west of Palatka. The exact location of the settlement where these specimens were obtained is not known. The same writer mentions the occurrence of similar rock at several points between Palatka and Tampa, but in no case does he give the exact localities.

---

[1] Wagner Free Inst. Sci. Trans., pp. 1553.

[2] Bailey, J. W., Amer. Jour. Sci., second series, 1851, vol. ii, p. 86.

While collecting statistics for the Tenth Census Dr. Smith[1] gathered much valuable information relating to the geology of Florida. The results of these geological investigations were published in 1881. After summarizing the previous literature Dr. Smith presented evidence to show that limestone of Vicksburgian age underlies nearly the entire peninsula of Florida. He gave in part its areal outcrop and noted the occurrence of *Orbitoides mantelli* and *Pecten poulsoni,* and other characteristic fossils in exposures of the limestone here called Marianna a few miles southeast of Campbellton, at the Big Spring, east of Marianna, and at other localities which he does not name. From a limestone collected by him six miles from St. Marks, in Wakulla County, Heilprin identified *Orbitoides mantelli* and pronounced the rock to be "Vicksburg," but the rock at St. Marks is now known to belong to the Apalachicola group instead of the Vicksburg. Dr. Smith examined a marl which occurs at various points along the Gulf coast and decided that it also was of Vicksburg age. He states that this marl forms the basis of the "Gulf Hammock" land in the coastal counties from Wakulla County nearly to Tampa Bay in Hillsboro County. In describing the areal extent of the "Vicksburg," Smith included in it large areas of rock which is now known to belong to the upper Oligocene or Apalachicola group; for example, the limestone extending along the Suwanee River for many miles, and the limestone at Tampa were, on the observations of others, wrongly included in the Vicksburg. He called attention to the fact that the Vicksburgian limestone is the prevailing rock in the vicinity of Gainesville and that it is often composed largely of *Orbitoides mantelli.* Other localities included in the Vicksburg were Payne's Prairie and Ocala.

In addition to the localities mentioned above, Smith reports limestone of Vicksburg age at Live Oak and Lake City in the northern part of the peninsula. At these localities, as in many other parts of the peninsula, the formation is overlain by a few feet of younger rock. Dr. Dall[2] gives the following summary of localities where the "Vicksburg" limestone has been observed:

> It is impracticable with the data yet printed to determine exactly at how many of Smith's localities the country rock belongs to the Orbitoides horizon. Some of them, doubtless, will eventually be shown to be of later age, as will be indicated later in this summary. Only those where no doubt seems to exist will be specified here. In Alachua County it is widespread, having been observed by Smith and Dall at Gainesville and westward to and about Archer, though in many places overlain by solutionary residium, remnants or even beds of later age but moderate thickness. It had been identified at Silver Spring, 6 miles east

---

[1] Am. Jour. Sci. (3) xxi, 292-309, 1881.

[2] Op. cit. pp. 102-103.

> from Ocala, by Le Conte, as early as 1861,[1] and subsequently the observation has been confirmed by Smith. Specimens of this rock have been collected by Willcox at Martin station, Marion County, about 8 miles north of Ocala, where the rock is very cherty; and at Jarves' Spring, on the southern border of Pasco County; at Fort Foster, on the North fork of the Hillsboro River, where, as in many other places, relics of the old Miocene beds overlie it. Several of the localities referred to by Heilprin must remain for the present on the doubtful list, but among them should hardly be counted the islet at the mouth of the Homosassa River, from which Mr. Willcox obtained the *Pygorhynchus* (*Ravenelia*) *gouldii* Bouvé, a small echinoderm originally described from the buhrstone (ante-Clairbornian) of Georgia.

It will be seen from this quotation that later investigations indicate that the limestone at some of the localities mentioned by Smith is not all of Vicksburgian age. However, this should not be regarded as detracting from the value of the earlier work, for with the increase of knowledge it is inevitable that formation lines should be shifted and that new formations should be discriminated.

Miss Maury's[2] summary of the Vicksburgian indicates that it forms a large part of the country rock in north central Florida, and she cites many of the localities mentioned by Dall and Bailey. She mentions especially the exposures seen in the vicinity of Gainesville, which are surrounded by rocks belonging to the subdivision here called Apalachicola group. Attention is also called to the occurrence of gypsum, which is regarded as the result of the action of sulphur on calcium carbonate, and the occurrence of phosphate rock resulting from an analogous chemical action.

During the progress of recent field work the occurrence of the Marianna limestone was noted at Natural Bridge in north central Walton County, but there is no indication that it reaches the surface west of this county; indeed, from well records and exposures of other formations, there is every reason to believe that in Escambia and Santa Rosa Counties, this formation lies some hundreds of feet below the surface of the upland.

East of Marianna the formation is exposed at several localities where it presents considerable variation in its lithologic characteristics. At some of these localities it is a soft, porous, white limestone, while in other places it is a tough, dense, gray limestone. However, some of this difference in texture may be accounted for by the fact that the rock hardens upon exposure to the air, and it is perhaps a significant fact that the hard, gray limestone usually occurs at natural exposures while the soft, porous rock is seen in the quarries.

---

[1] Am. Jour. Sci., 2nd ser., 1861, vol. xxi, pp. 1-12.

[2] Maury, Carlotta Joaquina. The Oligocene of western Europe and southern United States. Bull. Amer. Paleont., vol. iii, No. 15, 1902, pp. 45-46.

Near the east edge of the town of Marianna there is a small exposure which affords the following section:

SECTION No. 1.

Red, sandy clay, with some beds of sand and gravel, Lafayette	25 ft.
Marianna limestone:	
White, marly clay	5 ft.
Hard, earthy, gray limestone	2 ft.
Blue marl with many Pectens	8 ft.
Hard gray limestone	4 ft.

Approximately twenty feet below this is section No. 2.

SECTION No. 2.

Hard, gray limestone, very fossiliferous, *Orbitoides mantelli, Pecten poulsoni,* etc.	5 ft.
Dark gray chert	4 in.
Soft, porous, white limestone, with a few *Orbitoides* and other fossils	30 ft.

The white limestone of this section is exposed in a quarry where it is obtained by sawing. It is used locally for building purposes, especially in the construction of chimneys; upon exposure to the weather the rock hardens until it resembles the hard member at the top of the section.

A well drilled at Marianna penetrated limestone, marl and clay to the depth of 265 feet, where a bed of quicksand was encountered. An incomplete log of this well is given below:

Sand and sandy loam, Pleistocene	1½ ft.
Red and yellow sandy clay and sand, Lafayette	20 ft.
Alternating beds of hard limestone and marl	45 ft.
(This doubtless includes section No. 1 at the east end of the town.)	
Hard rock (chert) followed by alternating beds of marl and limestone with some chert, Marianna (?)	200 ft.

The log of this well does not afford any means of judging at what depth the base of the Marianna limestone was reached, but it is possible that an underlying formation was penetrated some distance above the quicksand.

At a locality two and a half miles southeast of Chipley, the Marianna limestone outcrops in the edge of a sink; and about six miles southwest of Chipley and one mile north of Duncan it is exposed in some small quarries where it had been obtained for building purposes. At one of these quarries belonging to Mr. F. G. Owens, the rock has also been burned for lime, which was reported to be of good quality. This quarry shows about twenty feet of porous, white limestone, resembling the rock in section No. 2 at Marianna. Near the surface it is very hard and durable, but at greater depth it becomes much softer.

Fossils occur throughout the entire section, but are especially numerous in the upper five feet, where the rock appears to be largely composed of *Orbitoides mantelli.* The rock, where it is quarried at this locality, appears to form a well defined ridge covered by a few feet of white Pleistocene sand and sandy loam, but its presence is indicated at various points by numerous boulders containing characteristic organic remains.

A few miles northeast of Duncan at Falling Water, a large sink exposes several feet of light gray limestone, probably belonging to the same formation. At this locality there appears to be a well defined system of underground drainage, which is indicated at the surface by numerous sink-holes. The best exposure is seen where a small stream plunges into one of these sink-holes. The stream is reported to have a fall of over seventy feet. The rock here forms a nearly perpendicular cliff and hence the section is not easily accessible.

At Natural Bridge near the north line of Walton County, a light-gray to yellowish-gray marl forms the arch which spans a small stream. The width of the channel is probably twenty feet and the length of the bridge about one-fifth of a mile. The height of the exposure was estimated by Vaughan[1] to be about thirty-five to forty feet above the level of the water in the creek. When fresh, this rock is soft and crumbles readily in the fingers, but when exposed to the weather it hardens rapidly and assumes the yellowish color mentioned above. It is quarried by sawing and is locally known as chimney rock, because it is used in the construction of chimneys. A considerable percentage of clay, which occurs in fine particles distributed through the rock, indicates that the material is a marl rather than a limestone. *Pecten poulsoni* is the most abundant fossil. From the lithologic character of the rock, together with the occurrence of numerous specimens of the species mentioned above, the rock is considered to belong to the Marianna limestone.

A quarter of a mile south of the Bridge near a turpentine still a similar marl is exposed in the bed of a small stream. The outcrop at this locality has a thickness of about twenty feet and it differs lithologically from the marl of the Bridge in being slightly more compact and of a distinctly grayish or bluish color. However, these differences are probably due to the fact that this exposure has not suffered so much weathering as the one at the Natural Bridge, and the substantial equivalence of the rock at the two localities can hardly be questioned. Numerous concretions of nearly pure carbonate of lime are scattered throughout this marl, but they do not appear to have any relation to the occurrence of the fossils.

About seven miles southwest of Marianna and nearly one mile from Kynesville, a number of fragments of limestone were obtained

---

[1] Vaughan, T. Wayland, unpublished notes.

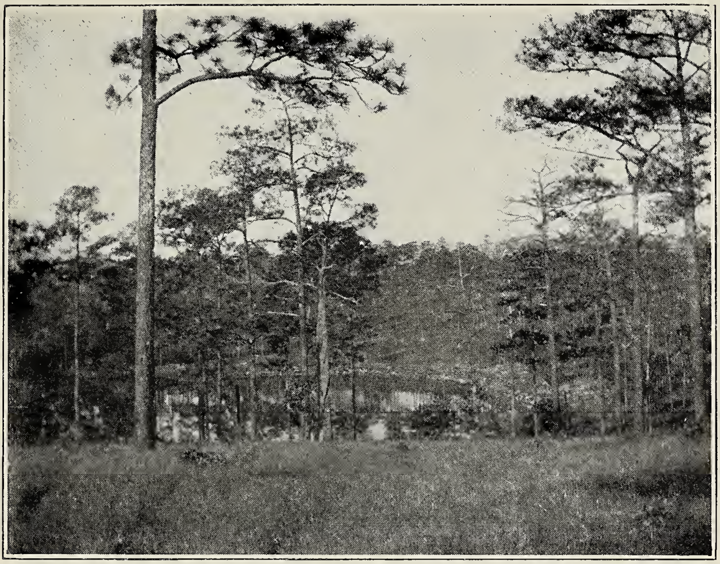


FIG. 1.—SINK HOLE CONTAINING POND, TEN MILES SOUTHWEST OF VERNON, WASHINGTON COUNTY, FLORIDA. TYPE OF TOPOGRAPHY OF THE VICKSBURG GROUP.

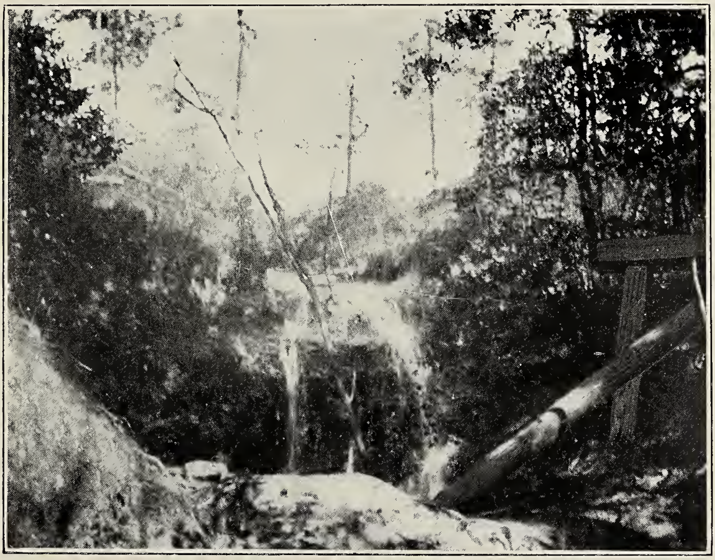


FIG. 2.—"FALLING WATER," FIVE MILES SOUTH OF CHIPLEY, FLA. THE SMALL STREAM FALLS INTO A SINK ABOUT SEVENTY FEET DEEP.

from a field where they were said to have been turned up by the plow. They represent a very cherty phase of the Marianna, and are probably the residual products of weathering. They consist of boulders up to two or three feet in diameter containing innumerable specimens of *Orbitoides mantelli* and *Pecten poulsoni.*

At the phosphate mines in the vicinity of Croom, a number of specimens of *Orbitoides mantelli* were collected and the rock here has the lithologic characteristics of the "Peninsular" limestone. The collection was made from boulders dredged from a mine, and hence may not be sufficiently characteristic to decide whether this is "Peninsular" or Ocala limestone. The presence also of a number of specimens of *Cassidulus* suggests that limestone belonging to the Apalachicola group is also represented. In the absence of characteristic nummulites in the collections, it appears not unlikely that the limestones of the Apalachicola group may here rest upon the "Peninsular" limestone. However, this conclusion is made subject to revision in case future collections from this locality should reveal the presence of fossils belonging to the Ocala limestone.

The "Peninsular" limestone is known to occur throughout the central part of the peninsula, where it may be observed in numerous natural and artificial exposures. It has been encountered in many of the hard rock phosphate mines from Croom northward nearly to the north line of the State. It is also known to underlie a large part of the central lake basin of the peninsula. This limestone is encountered in wells along the east coast from Fernandina southward beyond Palm Beach, and along the west coast south of Tampa.

OCALA LIMESTONE (NUMMULITIC ROCK.)

The Ocala limestone was formerly regarded as part of the "Orbitoides" limestone, but in 1882 nummulites derived from waste products of the Ocala limestone were described by Heilprin. The specimens were obtained by Willcox[1] on the Chassahowitzka River, and their association with fresh-water forms of recent shells was rightly interpreted to mean that the nummulites had been transported from some other locality and re-deposited with the younger shells. In 1884, Willcox[2] announced the occurrence of the nummulitic rock in place some distance above the original locality on the Chassahowitzka River and Heilprin, in commenting upon the announcement, stated that the beds belonged to the Oligocene.

---

[1] Heilprin, Angelo. On the occurrence of nummulitic deposits in Florida, and the association of nummulites with a fresh water fauna. Acad. of Nat. Sci., Phila., Proc., 1882, pp. 189-193.

[2] Science, N. S., vol. iii, 1884, p. 607.

In subsequent publications by the same author this rock was called the "Nummulitic" limestone, but, in 1892, Dall[1] proposed the name Ocala limestone.

Stratigraphic Position:—The Ocala limestone lies stratigraphically between the "Peninsular" and the beds here designated Apalachicola group. Lithologically, it bears a strong resemblance to the underlying "Peninsular" limestone, with which it also has a close faunal relation. These facts have led to the conclusion that the two formations are conformable, and it has also been suspected that the Ocala limestone represented a local phase of the "Peninsular." While the two formations are probably conformable, the extensive distribution of the nummulites of the Ocala limestone shows that it represents a widespread change in conditions and is not to be classed as a mere local phase of the underlying beds.

The Ocala limestone, as already noted by Johnson,[2] is sometimes wanting, so that the overlying formations rest directly upon the "Peninsular." This relation was noted at several localities which will be mentioned in discussing the younger formations. At present it is sufficient to note its absence and to suggest that since the Ocala limestone does not appear to be a local phase of the "Peninsular," there is probably a stratigraphic break between the rocks belonging to the Vicksburg and Apalachicola groups in the central part of the peninsula.

Lithologic Character: — The Ocala limestone consists of a soft, porous, light-gray to white limestone which bears a strong lithologic resemblance to the underlying "Peninsular" limestone, but is distinguished from it by the included fossils. When slightly weathered, the rock becomes light yellow, and owing to its granular appearance is often regarded as sandstone. The removal of the calcareous material by the leaching action of underground water leaves a pale yellow, more or less incoherent sand, containing a small percentage of calcium carbonate. When fresh, the Ocala limestone is so soft that it is easily broken, but exposed surfaces often become hardened by the deposition of calcium carbonate from the waters which emerge along the outcrop. For this reason the rock frequently appears to be hard and firm. Its porosity and ready solubility permit the formation of numerous underground channels which are sometimes seen at the outcrop and are inferred from the presence of numerous sink-holes. The rock contains an abundance of organic remains which are commonly preserved as casts. Nodules and large masses of chert are also common and in some localities a large part of the rock has been silicified.

---

[1] Dall, Wm. H. Neocene of North America, U. S. Geol. Surv., Bull. 84, 1892, pp. 103-104.

[2] Johnson, Lawrence C. Op. cit.

Thickness:—No definite determination of the maximum thickness of the Ocala limestone has been made, and as yet no exposures have been observed which show the contact with the underlying "Peninsular" limestone. All the information now available indicates that the thickness may be variable, and that the variation is in considerable measure due to subsequent erosion rather than inequalities of deposition. In the Transactions of the Wagner Free Institute of Science, Dr. Dall[1] states that at the type locality the Ocala limestone has been quarried to a depth of twenty feet without reaching its contact with the underlying "Peninsular" limestone. The greatest thickness noted during the recent field investigation was in a sink-hole near Ocala where the formation is exposed to a depth of about forty feet without reaching its base. This locality is described in a subsequent part of the discussion.

Physiographic Expression:—As in the case of the "Peninsular" limestone, the Ocala limestone is soft and porous, and hence gives rise to a topography which is characterized by underground channels, sink-holes, sinking streams, natural bridges, and large springs. The limestone has an important influence in the formation of many of the lake basins, and it forms the natural bridge of the Santa Fe River near High Springs. Large springs from the Ocala limestone are numerous in the central part of the peninsula.

Paleontologic Characters:—The Ocala limestone, like the underlying "Peninsular," is characterized by a great number of foraminifera, but it differs from the latter in the presence of nummulites. A few mollusks are said to be restricted to this formation, but as yet the fauna is very imperfectly known, and future study may add to the number of fossils which are peculiar to it.

Structure:—The Ocala limestone shows the same structural features as the underlying "Peninsular," and there is little reason to doubt that both have been subjected to the same movements since their deposition.

Local Details:—One of the earliest statements relating to the type locality of the Ocala limestone was made by Prof. LeConte in his description of the Silver Spring.[2] He says (p. 11):

> As in some measure related to the peculiar system of subterranean drainage above indicated, it may not be deemed inappropriate to conclude this communication with a few general remarks in relation to the physical causes which have produced the several qualities of surface soil which are found in the neighborhood of Ocala and the Silver Spring. The whole of this portion of the Penin-

---

[1] Dall, Wm. H., Trans. Wagner Free Inst. Sci., vol. iii, pt. 6, 1903, p. 1556.

[2] Le Conte, Prof. John. On the optical phenomena presented by the "Silver Spring" in Marion County, Florida. Am. Jour. Sci., 2nd series, vol. xxxi, 1861, pp. 1-12.

> sular appears to have been originally composed of a mixture of sand and shell-limestone; probably of the Eocene period. The lime-rock comes to the surface almost everywhere; in some cases it is composed of nearly pure carbonate of lime; in others silicification, to a greater or less extent, has taken place by the displacement of the lime by silex. But in all cases where its structure can be made out, it consists of a mass of conglomerated shells.

A later paper by Conrad[1] mentions some of the fossils found in the Ocala limestone, and correlates it with the Shark River Eocene of New Jersey. However, neither Prof. Le Conte nor Conrad made any special study of the Ocala limestone, and it remained for later workers to recognize its distinctive characteristics.

The Ocala limestone was for a long time regarded as a part of the Vicksburg "limestone," as it was then known; but it was later separated from the Vicksburg. It was in 1882 that Mr. Joseph Willcox discovered a rock from the vicinity of Chassahowitzka River which he submitted to Heilprin[2] for identification. Heilprin recognized some of the fossils as nummulites, and to a new species belonging to this genus he gave the name *N. willcoxii*. In 1886 Prof. Heilprin[3] added another to the published list of localities where the nummulitic fauna is known to occur. This new determination was based upon the presence of *Nummulites floridanus* which was obtained near Arredondo about six miles southwest of Gainesville. The specimens were collected by Prof. G. A. Wetherby and Mr. Joseph Willcox.

In his paper on the Neocene of North America, Dr. Dall[4] mentions Prof. Heilprin's discovery of nummulitic rock in Florida and suggests the name Ocala limestone from the locality where it is best exposed. He states (p. 103):

> Among the rocks which until recently were not discriminated from the Orbitoides limestone, and which appear in central Florida directly and conformably to overlie the latter, though no one has described their contact, is a yellowish friable rock containing many foraminifera, conspicuous among which are two species of nummulites, *N. willcoxii* and *N. floridana* Hp. This rock was first brought to notice by Mr. Joseph Willcox, and to Prof. Heilprin we owe a description of it which discriminates between it and the Vicksburg or Orbitoides rock. The rock was early recognized as Eocene, though not discriminated from the earlier beds. It is best displayed at Ocala, Florida, where it forms the country rock, and has been quarried to a depth of 20 feet without coming to the bottom of the beds.

---

[1] Conrad, T. A. Observations on American fossils with descriptions of two new species. Proc. Acad. of Natural Sciences, Philadelphia, 1865, p. 184.

[2] Heilprin, Angelo. Proc. Acad. of Nat. Sci., Philadelphia, 1882, pp. 189-193. Abstract of same, Am. Jour. Sci., 3rd ser., vol. xxiv, 1882, p. 294.

[3] Heilprin, Angelo. Notes on the Tertiary geology and paleontology of the southern United States. Am. Jour. Sci., 3rd series, vol. xxix, 1885, p. 69.

[4] Dall, Wm. H. Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, pp. 103-104.

After summarizing the results of previous investigations, Dall[1] mentions the following new localities where the Ocala limestone is exposed:

> Since then Mr. Willcox has obtained the rock in place 15 miles northeast of the original locality, from the shore of Wacassassa Bay, near Cedar Key, and also from the banks of the Wacassassa River, Levy County; from a "sink-hole" at Pemberton's Ferry[2] on the Withlacoochee River; about 10 miles eastward from Brooksville and also at Bayport, Hernando County, and at various places about Ocala. Prof. Wetherby has also sent specimens from a well 5 miles southwest of Gainesville, Alachua County, and Mr. L. C. Johnson reports it from an old Confederate iron furnace, 3 miles north of Levyville, Levy County, where it is only 20 feet thick and is covered with a bed of bog-iron ore formerly worked. Pemberton's Ferry is the most southern point at which it has been recognized at the surface, but at Bartow, Polk County, it occurs covered by about 6 feet of later strata.

From the character of its included organic remains the exposure at Martin Station[3] is regarded as equivalent to the Ocala limestone. At this locality, the rock is more or less silicified and hence has been found useful for railroad ballast, road metal and other purposes where durable material is needed.

To the rock at the old Confederate iron works in Levy County, Mr. Johnson[4] gave the name "Levyville formation," and states that it consists of about twenty feet of soft, porous building stone. He believed that it has been partially removed by erosion in the western part of the peninsula where it is much thinner than farther east. He also expressed doubt as to its ever having been deposited over the entire surface of the underlying Vicksburg.

Several other localities were mentioned where this formation was recognized, among them being Payne's Prairie. At a quarry on the Newnanville road near the Santa Fe River, Johnson reports that the Neocene formations rest directly upon the limestone of Vicksburg age the nummulitic rock (Ocala) being absent. Johnson's Levyville formation has usually been regarded as the substantial equivalent of the Ocala limestone; but it is not possible at the present time to verify the determination of the nummulites, and the rocks at Levyville may really belong to some other formation.

In 1902 Miss Maury[5] summarized the known distribution of the Ocala limestone, but did not give any new information relating to it.

---

[1] Ibid. p. 104.

[2] Now called Croom.

[3] Dall, Wm. H., Trans. Wagner Free Inst. Sci., vol. iii, pt. 6, 1903, pp. 1156-1157.

[4] Johnson, Lawrence C. Op. cit.

[5] Maury, Carlotte Joaquina. A comparison of the Oligocene of western Europe and southern United States. Bull. of Am. Paleon., vol. iii, No. 15, 1902, p. 47.

She appears to have obtained her facts relating to the formation from some of the publications already mentioned.

The Ocala limestone is extensively exposed at the type locality where it has been quarried for the construction of roads and the manufacture of lime. Exposures are occasionally seen in the walls of sinks and its presence may also be inferred by the appearance of numerous boulders containing nummulites. These scattered fragments are frequently found resting upon the surface sands and are usually rather firmly cemented, probably by an accumulation of silica and iron. A thin deposit of sand is commonly found resting upon the uneven surface of the limestone. In such cases the sand appears to be largely the result of disintegration of the country rock, and it is therefore residual. While this statement concerning the origin of such sands may seem improbable, it is explained by the fact that the soil formed from the limestone is the insoluble material left after solution has removed the calcium carbonate. Consequently the residual sands constitute the impurities of the original rock and may in some cases have formed only a small percentage of the whole. Since the publication of Dall's report, quarrying at Ocala has been carried to a somewhat greater depth. The quarry of the Florida Lime Company, situated near the southwest corner of the city, now shows:

Sandy loam with more or less organic matter Pleistocene...........	1 ft.
Sand, pale yellow, residual	1-4 ft.
Light gray to white nummulitic limestone (Ocala)..................	25-30 ft.

In this quarry the fossils occur throughout the greater portion of the limestone, but are especially numerous near the top where the removal of the calcium carbonate has loosened the casts of the organic remains. In addition, the quarry presents certain other points of interest in the arrangement of the cherty portions of the rock. Chert nodules occur in various parts of the section and in places two sets of vertical silicified bands were noted. These cherty bands are at approximately right angles to each other and probably represent planes of silicification along vertical joints.

A good section of this limestone is exposed in another quarry situated on the north side of the road to Silver Spring about a half mile east of the town. At this locality, the rock, which is considerably decomposed, has been quarried to a depth of forty feet and contains an abundance of nummulites.

About twenty feet of Ocala limestone is exposed in a third quarry situated a quarter mile north of Ocala, and about fifteen feet of the same rock was seen in a quarry two and a half miles southwest of the city. One of the most important sections may be seen in a sink-hole about three miles southwest of Ocala. This sink-hole is approximately forty feet deep and affords entrance to a small cavern which may be

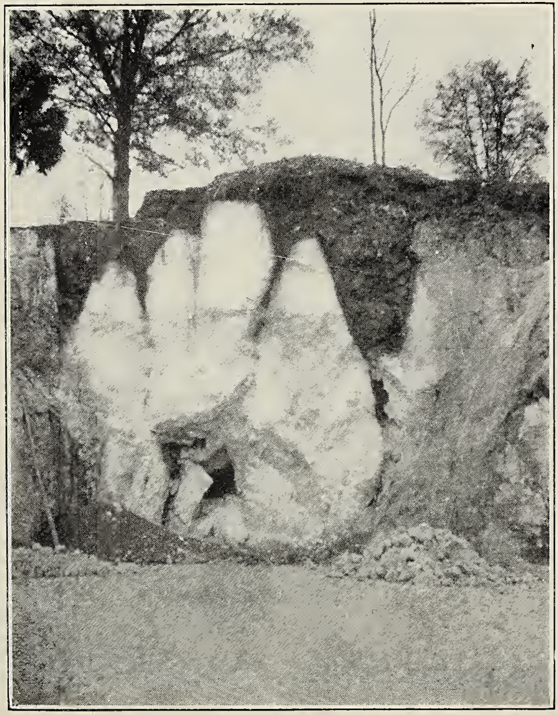


FIG. 1.—QUARRY OF OCALA LIME CO. (OLD PHILLIPS QUARRY) ONE MILE SOUTHEAST OF OCALA, FLA., SHOWING DECOMPOSED ZONES AND SOLUTION CHANNELS IN OCALA LIMESTONE.

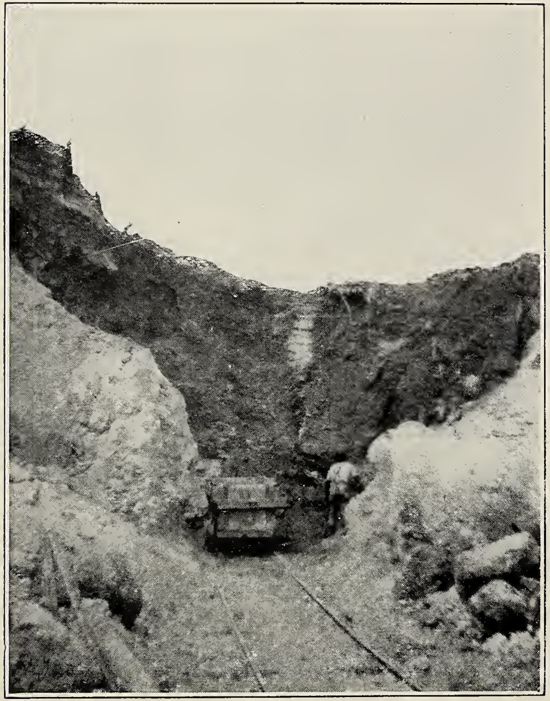


FIG. 2.—OCALA LIMESTONE LEDGES IN PIT OF FORT WHITE HARD ROCK COMPANY, FORT WHITE, FLA.

penetrated a short distance. Mr. Clapp reports that nummulites occur down to the base of this exposure, but are not so numerous as at some of the other localities. Lithologically this rock is essentially the same as that exposed at the quarry of the Ocala Limestone Company, and the section shows the maximum observed thickness of the formation.

At the old "Phillips" quarry, one mile southeast of Ocala, there is a section which shows about twenty-five feet of soft, porous, light-gray limestone which contains an abundance of chert throughout the entire section. Since this rock contains many nummulites, its identification as the Ocala limestone can scarely be questioned. Solution cavities are common and along certain vertical crevices the rock has been removed, forming passages two or three feet in width. These have been filled by the settling of the overlying sandy clay.

On the Anclote River, about one mile from Tarpon Springs, there is an exposure showing from two to three feet of nummulitic limestone which extends some distance up the stream. The rock here lies near the surface over a considerable area and boulders containing nummulites are common. A similar exposure of Ocala limestone was noted near Port Richey on the Pithlachascotee River where the rock is said to outcrop over a considerable area. At the mine of the Fort White Hard Rock Company, one-half mile southwest of Fort White, the Ocala limestone is well exposed. In the north pit belonging to this company, the following section was observed:

Light-gray sandy loam, Pleistocene	4-8 ft.
Fine, even-grained, yellow sand, residual..................................	20 ft.
Limestone and phosphate rock, Ocala limestone.....................	25-30 ft.

In this pit the Ocala limestone occurs in irregular ledges separating the phosphate rock which appears to be in part the result of replacement of the country rock. The limestone ledges commonly form two discontinuous series at approximately right angles to each other, the intervening space being occupied by the irregular bodies of phosphate rock. In general, the limestone bands thicken toward the base of the pit, and the phosphate deposits become smaller. Both the limestone and phosphate are more or less cherty, but the silicification appears to be in the form of nodules and small boulders rather than extensive replacement. Fossils are very abundant in the limestone, prominent among them being the characteristic Nummulites of this formation. At the mine of the Cummer Lumber Company, four miles west of High Springs, there is a similar exposure of the Ocala limestone. At this locality the rock lies much nearer the surface, the total thickness of overlying sand being seldom greater than ten feet. There is the same characteristic arrangement of the limestone and phosphate rock as at Fort White.

Similar relations between the Ocala limestone and the phosphate were observed at the mine of the Union Phosphate Company, seven miles east of Newberry. The Alachua sink was visited by Mr. Clapp, who reported an exposure of about ten feet of soft, white limestone containing many flint nodules. From the collections made at this locality it is evident that the Ocala limestone forms part of the walls of the sink and it also appears probable that the overlying Hawthorne formation is present. On the island across the Indian River from Melbourne, Dr. Sellards reports the occurrence of the Ocala limestone at a depth of 221 feet. This determination was made from fragments of the rock obtained by Mr. Oliver Gibbs in drilling a well. The rock was found to contain nummulites, and although the specimens were not specifically determined, the occurrence of the genus appears to warrant its correlation with the Ocala limestone. This is a point of special interest because it shows the Ocala limestone to be nearer the surface in that part of the State than would naturally have been inferred from previous publications.

The Ocala limestone is known to be well exposed at various points in the region where rock phosphate is being mined. Nummulites have been collected from various mines in the vicinity of Hernando, Citrus County. In a pit Sec. 10, T. 18, S. R. 19 E, the following section was observed:

Yellow sand, with phosphatic gravel and brown and yellow clays; also phosphatic white and gray sand, sometimes greenish........	2-3 ft.
Phosphatic bluish-gray clays, some hard sandstone with boulders of hard rock phosphate containing nummulites.	

The entire section probably represents altered and weathered phosphatic Ocala limestone.

Nummulites were also obtained by Eldridge from a stone quarry on the Burns place one and a half miles southwest of Owensboro, Citrus County, and on Mr. Clement's mine No. 8, on the east side of Blue Springs, T. 16 S., R 19 E.

Miliolite Limestone:—In 1887 Heilprin[1] noted at Wheeler's, on the Homosassa River, the occurrence of a porous and cavernous limestone, which he called *Miliolite limestone* because of the presence of many foraminifera belonging to the Miliolidæ. Dall[2] reports similar rock six miles southwest of Lake City, and thinks the *"Miliolite"* limestone belongs with the other foraminiferal limestones; but he does not express an opinion as to whether it belongs with the "Peninsular" or Ocala limestone. The *"Miliolite"* limestone is here placed with the Vicksburg group, and is tentatively referred to the Ocala limestone, to which it probably belongs.

---

[1] Heilprin, Angelo. Explorations on the West Coast of Florida, Wag. Free Inst. Sci., Trans., vol. i, 1887, p. 57.

[2] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1592, pp. 104-105.

APALACHICOLA GROUP.

Prior to 1887 the rocks belonging to the group here designated Apalachicola group from the exposures along Apalachicola River, in western Florida, were included with the Eocene and were regarded as part of the "Vicksburg" ("Orbitoides") limestone. In that year Langdon[1] observed a group of beds occurring on the Apalachicola River which he referred tentatively to the lower Miocene, designating them the Chattahoochee group. With the Miocene beds Dall,[2] in 1892, included not only the Chattahoochee group of Langdon, but the Hawthorne formation, the so-called "Waldo formation," the "Tampa limestone," the "Tampa silex bed," the Chipola marl, the Alum Bluff formation and certain sands, gravels and clays, which he did not specifically name.

The use of the name Miocene to designate the group here called Apalachicola continued for a number of years, the Oligocene beds being often called "Old Miocene" or "Sub-tropical Miocene," to distinguish them from the "new" or "cold-water" Miocene. In 1896 Dall[3] discussed the faunal reasons for regarding the "Old Miocene" as Oligocene, and in his publications since that date he has restricted the term Miocene to later beds (here called Jacksonville limestone and Choctawhatchee marl). However, the Chattahoochee formation is still included in the Miocene by both Smith[4] and McCallie.[5]

The Apalachicola group was formerly designated the Chipolan stage[6] and the Chipola group,[7] but these names are abandoned because the name Chipola has been used to designate a marl belonging to the group.

The Apalachicola group includes a number of beds differing widely in lithological character, though they are recognized by their fossils as integral parts of a single group. While limestones and marls predominate, the group also includes beds of nearly pure sand and clay. The entire period of deposition appears to have been characterized by the accumulation of more or less terrigenous materials, and hence the limestones are usually rendered somewhat impure by an admixture of clay and sand. At certain times the conditions appear to have been especially favorable for the development of organic life and some horizons, such as the Chipola marl member of the Alum Bluff formation, and the "silex bed" of the Tampa formation contain very large faunas.

---

[1] Langdon, Danl. W., Jr., Some Florida Miocene; Amer. Jour. Sci., 3rd ser., vol. xxxviii, 1889, pp. 322-324.

[2] Dall, Wm. H., Neocene of North America, U. S. Geol. Surv. Bull. 84, 1892, pp. 105-123.

[3] Dall, Wm. H., Descriptions of Tertiary Fossils From the Antillean Region, U. S. Nat. Mus. Proc., vol. xix, No. 1110, 1896, pp. 303-305.

[4] Smith, E. A., The Underground Water Resources of Alabama; Geol. Survey of Alabama, 1907, p. 81.

[5] McCallie, S. W., The Preliminary Report on the Underground Waters of Georgia, Geol. Surv., of Georgia, 1908, pp. 31 and 32.

[6] Dall, Wm. H., North American Tertiary Horizon, U. S. Geol. Surv., 18th Ann. Report, 1896-1897, p. 334.

[7] Foerste, A. F., Studies on the Chipola Miocene of Bainbridge, Ga.; and of Alum Bluff, Fla., Am. Jour. Sci., 3rd ser., vol. xlvi, 1893, p. 244.

Owing to the lithologic variations and widely separated exposures, the exact correlation of the formations of this group is dependent upon their organic remains. While the paleontological studies, especially those made by Dall, have shed much light upon the stratigraphic relations of the different beds, there are still many points which cannot as yet be fully decided. For this reason it seems best to retain the names of various beds and to indicate as far as possible their known relationships. The Apalachicola group is separated into four formations—the Chattahoochee, the Hawthorne, the Tampa and the Alum Bluff. There is, however, some reason for believing that the first three are, in part at least, synchronous, though exact equivalence is difficult to determine where outcrops are widely scattered and faunal variations are slight. The Alum Bluff formation is clearly younger than the Chattahoochee formation, upon which it rests.

The name Chattahoochee group was first applied by Langdon[1] to the beds occurring at a series of exposures along the Chattahoochee and Apalachicola Rivers. The localities examined by Langdon extend from the final disappearance of the Vicksburg, nine miles by water above River Junction (Chattahoochee) to the point where the Oligocene exposures give place to the overlying sands and marls of younger formations. The exposures examined are at Alum Bluff, Rock Bluff, Ocheesee and River Junction.

In 1893 the section along the Apalachicola River was examined by Foerste[2] who recognized the presence of three dissimilar groups to which he gave the names Chattahoochee, Chipola and Chesapeake. His paper gives considerable attention to the character of the materials comprising his Chipola and Chesapeake groups, with a view to correlating them with the non-marine deposits grouped under the names of

---

[1] Langdon, Daniel W., Jr., Some Florida Miocene. Amer. Jour. Sci., 3rd ser., vol. xxxviii, 1889, p. 322.

[2] Foerste, A. F. Studies on the Chipola Miocene of Bainbridge, Ga., and Alum Bluff, Fla., with an attempt at correlation of certain Grand Gulf Group beds with marine Miocene beds eastward. Amer. Jour. Sci., 3rd ser., vol. xlvi, 1893, pp. 244-254.

"Grand Gulf and Lafayette formation." The major portion of the discussion, however, deals with the conditions of sedimentation during the deposition of the rocks belonging to the various groups.

In 1892 Dall[1] divided the formations here called Apalachicola group into two groups, retaining the name Chattahoochee group for the limestones and marls which are extensively developed in the north-central part of the peninsula, and employing the name Tampa group to include the beds which he called Chipola marl, Alum Bluff sands, Sopchoppy limestone, Tampa limestone and Tampa silex bed. In his later paper on the Tertiary faunas of Florida, Dall places the "silex bed" at Tampa in his Chattahoochee group. The discovery of the characteristic species of the genus *Orthaulax* in the basal portion of the Chattahoochee formation led to this change in the correlation.

HAWTHORNE FORMATION.

In 1892 Dall[2] described, under the name of Hawthorne beds, some limestones, sands and clays, extensively exposed in the interior of Florida, which had been observed by L. C. Johnson. These beds are here designated the Hawthorne formation. At the time of the publication of Dall's report the Hawthorne formation was being quarried and had aroused considerable interest because of the presence of phosphoric acid in the rock. The formation consists of clays, sands and phosphatic limestones and lies stratigraphically between the limestones of the Vicksburg group and the Alum Bluff formation.

Stratigraphic Position:—The stratigraphic relation of the Hawthorne formation to the underlying rocks of the Vicksburg group has been observed at several localities in the interior of the peninsula. From what is said concerning the geologic history, it is apparent that the deposition of the Vicksburg group was followed by a widespread emergence of the land which permitted extensive erosion and the formation of hills and valleys. There is no doubt that this emergence and consequent erosion affected the central part of the peninsula, where the Hawthorne formation is well exposed, for this formation rests uncomformably upon either the Ocala or the "Peninsular" limestone at many localities. This relation is emphasized by the lithologic character of the beds, for there is an abrupt change from the soft fine-grained limestones of the Vicksburg group to the clays, sands and phosphatic limestones of the Hawthorne formation. The relation of the Hawthorne formation to the Alum Bluff formation has not yet been accurately determined, though, at De Leon Springs, Chipola fossils have been found in a marl overlying phosphate rock which belongs to this formation. At various points in the peninsula of Florida the Hawthorne formation is found resting unconformably upon limestone of Vicksburg age, and in the vicinity of Hawthorne thin beds of conglomerate occur in the base of the formation. At many of the phosphate mines in central Florida the limestones of the Hawthorne formation are found overlying either the Ocala limestone or the "Peninsular" limestone with an apparent unconformity, which has permitted the deposition of sands and some limestone beds along channels developed in the upper surface of the Vicksburg formations. It should be said, however, that in many of these cases the materials belonging to the Hawthorne formation appear to have been more or less disturbed since their deposition, and it is possible that at some localities the apparent unconformity may be due to the falling of the roofs of caverns developed near the contact of the two formations. The relation of the Hawthorne formation to the other members of the Apalachicola group has not been determined, but there is no doubt that its deposition was in part contemporaneous with the Tampa and Chattahoochee formations. In fact, while the absence of paleontologic information makes it impossible to correlate these formations on biologic grounds there is little doubt that they were all deposited during an extensive submergence which succeeded the emergence of the rocks belonging to the Vicksburg group. On physical grounds, therefore, there is good reason for regarding these formations as synchronous.

---

[1] Dall, Wm. H., The Neocene of North America, Bull. U. S. Geol. Survey No. 84, 1892, pp. 105-123.

[2] Dall, Wm. H. Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, pp. 107, et seq.

Lithologic Character:—According to Dr. E. H. Sellards the rock at the type locality at Hawthorne is a light-colored, soft, porous limestone. The original building stone quarry, which is located near the station of Grove Park, about three miles west of Hawthorne, is now abandoned and is badly overgrown, so that the thickness of this limestone cannot well be determined. At the old phosphate mine, which is at least a mile southwest of the stone quarry, the rock is a phosphatic conglomerate. At many localities the limestones of the Hawthorne formation are silicified, forming bowlders and beds of chert. This is a very common condition in the rock phosphate region where these limestones rest directly on those belonging to the Vicksburg group.

Beneath the phosphatic limestones of the Hawthorne formation are beds of sand, sandstone, or gravel, which are underlain by several feet of clay. The sand beds at some localities contain iron oxide which forms a coating on the grains of silica. The clays are greenish and locally sufficiently calcareous to be called a marl.

Thickness.—The thickness of the Hawthorne formation varies greatly, the maximum amounting to approximately ninety-five feet. The three members of this formation with their maximum observed thicknesses, according to Dall,[1] consists of greenish clay seventy feet, ferruginous yellow sandstone four feet and phosphate rock twenty feet. The maximum thickness of the Hawthorne formation, as given by the same author, is 125 feet.[2] However, over a large part of the peninsula, where the sole representative of the Hawthorne formation is the phosphatic or siliceous rock, the thickness is but a few feet.

Physiographic Expression: — The Hawthorne formation seldom has much influence upon the surface configuration in the region which it underlies. Locally, however, the cherty beds protect the underlying rock from erosion and thus give rise to ridges; and where the clays lie near the surface they are characterized by an erosion surface of moderate relief. The chert-capped ridges are usually inconspicuous, but in some parts of the phosphate region they are sufficiently marked to form well defined topographic features.

Paleontologic Character:—The fauna of the Hawthorne formation has received but little attention and is practically unknown. The green clay and sands are reported to contain many oyster shells which are thoroughly silicified, and the phosphatic limestones and the chert beds are characterized by numerous specimens of an echinoid belonging to the genus *Cassidulus.* Molluscan remains are associated with this echinoid, but they have not yet been investigated.

Structure:—The Hawthorne formation has been affected by broad earth movements similar to those which produced the peninsula of Florida. There is a gentle seaward dip which is seldom noticeable in single exposures, but may be determined by means of well records which show that the formation sinks below sea level on the east coast. There are probably dips both northward and southward from the central part of the peninsula, but the determination of their amount requires detailed study. The general easterly dips are known to be irregular in amount, but probably do not average more than 75-100 feet to the mile.

Local Details: — While the Hawthorne formation is well known, information concerning the detailed sections is comparatively meager. The most complete sections which have been recognized as belonging to this formation are those described by Dall.[3] At the type locality near Hawthorne the rock is phosphatic and has been mined and crushed for use as a fertilizer and at many other places the formation contains more or less phosphate. One of these localities is at the Devil's Mill Hopper northwest of Gainesville, where the rock is exposed in the walls of the sink, which has a depth of about 115 feet. Here the greater portion of the section belongs to the Vicksburg group, but a phosphatic rock near the top probably represents the Hawthorne formation. Another sink which exposes this formation is located in section 18, T. 7 S., R. 18 E. At this locality the section given by Dall[1] is:

---

[1] Dall, William H., Neocene of North America; U. S. Geol. Surv. Bull. 84, 1892, p. 109.

[2] Ibid. p. 158.

[3] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey Bull. 84, 1892, pp. 107-112.

> This place is locally known as "Nigger sink," and the Vicksburg limestone has been reached by a well hole in the center of it. Above the well the lower 10 feet of the wall of the sink is hidden by talus, but is believed to be clay of a greenish-yellow color, 30 feet of which rises above the talus, covered by a four-foot layer of firm, hard sand, almost a sandstone, and this by a sandy ferruginous layer of clay and gravel containing an oyster, like *O. virginica,* reproduced in chalcedony. This ferruginous layer, which will be referred to here under the term ferruginous gravel, seems to appear in many different sections, with its oyster and silicified corals. It also occurs in Georgia. Above it is a layer 2 feet thick of soft sandstone resembling the phosphatic rock in appearance. Covering this is a bed of sand and clay 8 feet thick containing fragments of all sizes, from a few pounds to a ton in weight, of the phosphatic rock and its large, silicified coral heads. These last, when they appear on the surface as around Archer, from the solution of the phosphatic matrix are popularly known as "fossil stumps" or "nigger heads." They are large masses of chert or chalcedony, often hollow, retaining on the surface more or less obscure indications of the original coral structure. Above this stratum come the surface sand and loam, here about 20 feet thick.

In this sink the well was drilled to limestone of the Vicksburg group, but the depth and character of the material penetrated are not given. The same writer gives more or less complete descriptions of several other sections.[2] One of these is in Newnansville, where the clay which immediately overlies the limestones of the Vicksburg group has a thickness of seventy feet and is overlain by two feet of ferruginous sand, three feet of undescribed material, and eight to twenty feet of phosphatic rock. About five miles east of Mixon's the ferruginous sand rests on the Vicksburg group and is overlain by the phosphatic bed, and nearer Archer the remnants of the phosphatic rock are found resting directly upon the Vicksburg. Occurrences of similar phosphatic rock are reported where the railroad crosses the Hillsboro River and at Jarves Springs; while at De Leon Springs a phosphatic rock is said to be overlain by beds containing Chipola fossils. The same phosphatic rock is also reported from Live Oak and Lake City, and the ferruginous bed with its silicified oysters is known to occur at Levyville and at Magnesia Springs. The following sections are given by Dall:[3]

---

[1] Loc. cit. p. 109.

[2] Op. cit.

[3] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey Bull. 84, 1892, pp. 110-111.

At White Springs on the Suwanee, the following section was obtained:

I.	Gray soil, sand, and humus	2 ft.
II.	White sand	4 ft.
III.	Clay with silicified corals and oyster (Hawthorne beds)	6-8 ft.
IV.	Indurated clayey rock (Hawthorne beds?)	2 ft.
V.	Clayey sand-rock, rather fine grained and soft	4 ft.
VI.	The same, somewhat coarser and harder	8-10 ft.
VII.	Sand rock of coarser sharp grains, coated and cemented together with white limy matter	4-6 ft.
VIII.	Foraminiferal Eocene top-rock (Vicksburg) indefinitely below.	

The silicified corals of bed III are sometimes 20-60 pounds in weight and along the river when dislodged from the clay often wear immense pot holes in the softer lime rocks. Miocene sharks' teeth and fragments of bone also occur in the clay. Under bed VIII, when it is tilted up, as occurs in various places along the river, is found the older Orbitoides limestone of the Vicksburg group.

In a sink 4 miles north of Lake City, the following section was observed:

I, II.	Sand and sandy soil	5 ft.
IV.	Indurated clayey rock	2 ft.
VII.	Lime cemented sand-rock	8 ft.
VIII.	Foraminiferal Eocene (indefinitely down).	

At White Springs numerous specimens of *Cassidulus* were obtained from a cherty rock which has been used in constructing a foundation for the spring house. According to reports, which were obtained from well-informed residents of the town, this rock was quarried from the river channel. At the time of the field investigations for this report the river was too high to permit an examination of the outcrop in the river channel; but a subsequent examination by Mr. Stephenson[1] resulted in finding the cherty beds of the Hawthorne formation in close proximity to exposures of the Alum Bluff formation. This strengthens the conclusion that was formed at the time of the earlier field work, that the *Cassidulus*-bearing zone lies near the top of the Hawthorne formation.

Two miles south of Lake City:

I.	Sandy soil	2 ft.
III.	Clay, with corals and oysters	20 ft.
VII.	Lime cemented sand-rock	3 ft.
VIII.	Foraminiferal Eocene (indefinitely below).	

Near the southern boundary of Columbia County, at Fort White, the rocks are gently folded and the surface has been more or less worn into basins containing phosphatic breccia of the older lime rocks, which are themselves under these basins of phosphate slightly phosphatized in their upper portions. Here, owing to the fact that the Miocene and Foraminiferal Eocene (Miliolite) beds have been more or less broken up by the action of water dissolving or wearing away the softer parts, the Orbitoides limestone sometimes immediately underlies the breccia in the basins and in other places the basins are composed of the Miliolite limestone. Beds VI, VII and VIII, of the above series are more or less silicified, or when broken up the resulting breccia contains numerous angular fragments of chert.

---

[1] Stephenson, L. W., Unpublished notes.

In the north-central part of the peninsula and extending as far south as Croom, there are many exposures of chert and cherty limestone which rest on the limestones of the Vicksburg group. This rock usually contains many casts and molds of an Echinoid, which Vaughan has identified as a *Cassidulus.* The rock appears to be very persistent but seldom attains any great thickness. At Bass Station, about six miles southwest of Lake City, it was quarried to a depth of twelve or fifteen feet without reaching the underlying Vicksburg group. About six miles west of Gainesville on the Newberry road, it appears to have a thickness of more than fifteen feet and to rest directly on the Ocala limestone, which forms the country rock of that region. The same Echinoid is found in cherty beds in many localities between Bass Station and High Springs and at Alachua sink, White Springs, Ellaville and Croom. It is also known at various localities in the hard rock phosphate region. At the railroad trestle just west of White Springs, there is an exposure of sands, marls and clay which is probably the local equivalent of the limestones belonging to the Hawthorne formation. At this locality the beds pass under the Chipola marl member. A section at the railroad trestle shows the following materials:

1.	Sandy loam	20+ ft.
2.	Soft friable marl containing some bands of chert and numerous Echinoids	10-15 ft.
3.	Soft marl containing oyster shells.	
4.	Light green thinly laminated siliceous clay	4 ft.
5.	Light green sand to water	4+ ft.
	Total	44+ ft.

CHATTAHOOCHEE FORMATION.

The limestones and marls exposed along the Apalachicola River have been grouped in various ways by different writers. In this paper the name Chattahoochee formation is restricted to those limestones and marls of northern and western Florida which lie stratigraphically between the limestones of the Vicksburg group and the Chipola marl member of the Alum Bluff formation. Beds of chert occur in this formation and thin layers of sand and clay are not uncommon. The type locality is at Chattahoochee Landing, where there is an exposure of light gray marl and impure limestone. This formation forms Langdon's[1] Chattahoochee group, and it is apparently the Chattahoochee group of Foerste.[2]

---

[1] Op cit.

[2] Op cit.

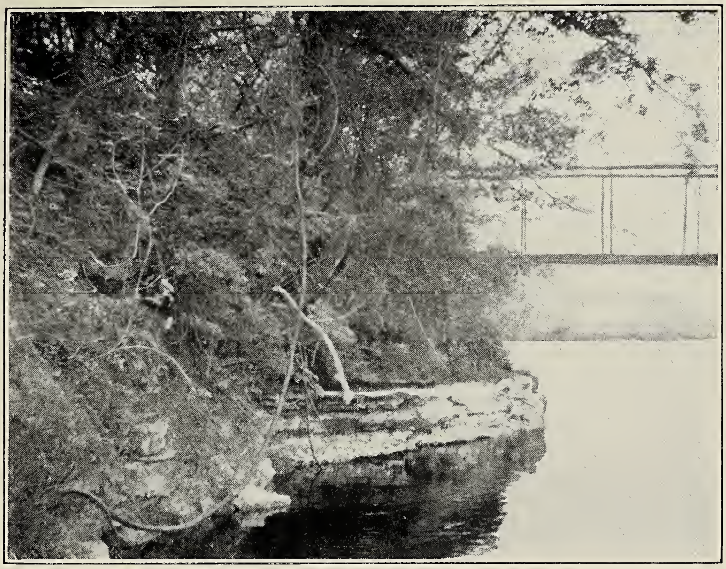


FIG. 1.—OUTCROP OF LIMESTONE OF HAWTHORNE FORMATION ON SUWANEE RIVER, OPPOSITE ELLAVILLE, FLA.

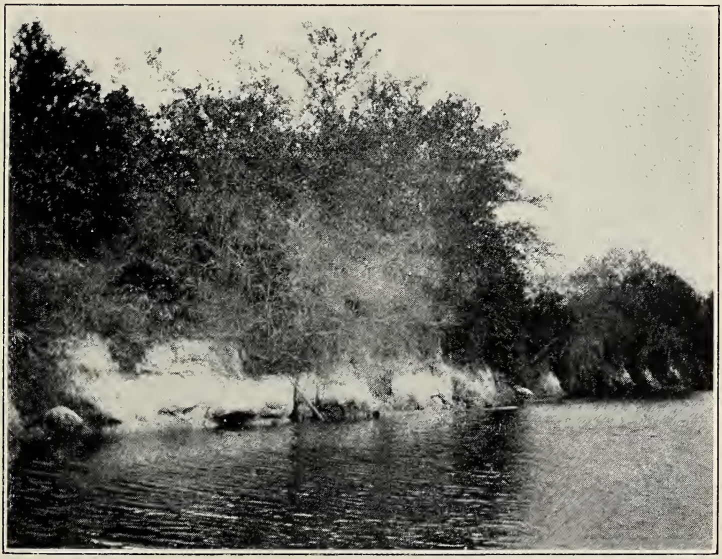


FIG. 2.—LIMESTONE OF TAMPA FORMATION EXPOSED ALONG SIX-MILE CREEK, ONE-FOURTH MILE BELOW A. C. L. R. R. BRIDGE, HILLSBORO COUNTY, FLORIDA.

In 1892 Dall[1] called this formation "Ocheesee beds," but in a subsequent paper he notes the absence of exposures at Ocheesee[2] and uses the names Chattahoochee formation[3] and Chattahoochee limestone.[4] As the formation contains considerable marl, the use of Chattahoochee limestone is not entirely satisfactory, and hence the name Chattahoochee formation is retained.

Stratigraphic Position:—The Chattahoochee formation is known to rest unconformably on the underlying limestone of the Vicksburg group in southern Georgia. The evidence upon which this unconformity exists was summarized by Pumpelly in 1893.[5] According to this writer, there is usually a limestone conglomerate at the base of the Chattahoochee formation in southwestern Georgia, and the altitude of the contact between the two limestones varies considerably within short distances. The variations in altitude given by Pumpelly might, if considered alone, be regarded as due to deformation rather than to an erosional unconformity, but the evidence of erosion is strongly supported by the conglomerate which in some places resembles breccia, but in other localities contains rounded pebbles of the underlying rock. The difference in lithologic character between the limestones of the Vicksburg group and the Chattahoochee limestones is so marked that it would hardly be possible to mistake the source of these pebbles. The argument in favor of the inequalities of the surface of the limestones of the Vicksburg group being due to erosion is strengthened by the paleontologic evidence. On evidence furnished by Foerste, Pumpelly states that the Chattahoochee at Griffins Creek contains a fauna characteristic of the upper part of the Vicksburg group, while the other localities examined contain faunas belonging to the lower part of that group. It thus appears that at Griffins Creek the deposition did not begin until after the formation of the beds exposed in the immediate neighborhood, or, in other words, that an island consisting of the underlying limestones of the Vicksburg group was not submerged until after the deposition of the lower part of the Chattahoochee formation.

Tuomey also collected corals at the contact between the Chattahoochee and the underlying limestones, and Dr. Dall identified these as belonging to the base of the Miocene, to which the members of the Apalachicola group were formerly assigned.

---

[1] Dall, Wm. H., Neocene of North America, U. S. Geol. Surv. Bull. 84, 1892, pp. 105-107.

[2] Dall, Wm. H., and Stanley-Brown, Joseph, Cenezoic Geology along the Apalachicola River, Geol. Soc. Am., vol. v, p. 154, 1894.

[3] Ibid, p. 152.

[4] Ibid, p. 155.

[5] Pumpelly, Raphael. An apparent time break between the Eocene and Chattahoochee Miocene in southwestern Georgia. Am. Jour. Sci., 3rd ser., vol. xlvi, 1893, pp. 445-448.

In Florida the base of the Chattahoochee formation was not seen, but there is little doubt that the pronounced unconformity observed farther north extends southward into that State. This view is strengthened by what is already known of the physical history of the State; and by the fact that both the Hawthorne and Tampa formations, which appear to have been deposited at about the same time as the Chattahoochee, rest upon an eroded surface of the limestones of the Vicksburg group.

Lithologic Character:—The Chattahoochee formation consists of light-colored limestones and marls, containing some thin beds of chert, clay and sand. The colors vary from creamy white to light gray or green on recently exposed surfaces to light yellow, brown or more rarely, pink, on weathered outcrops. Lithologically, there is a gradation from nearly pure limestone to sands and clays, but, in general, the argillaceous and siliceous limestones predominate, forming impure limestones or marls. The formation is in part composed of semi-crystalline limestone; but soft, loosely coherent rock resembling an impure chalk is more common. While chert beds occur at various horizons, they are much thinner and less persistent than those of the underlying group. At times, organic life appears to have been abundant, and hence some layers are very fossiliferous, though the fossils are usually preserved in the form of imperfect casts and molds which have been left by the solution of the shells.

Thickness: — Vaughan's[1] observations along the Apalachicola River show that the Chattahoochee attains a considerable thickness near the type locality.

> The Chattahoochee limestone at the Old Landing has a thickness of at least 85 feet and probably is greater because the basal 20 feet of the two sections measured on the roads to the water's edge at the river are not exposed. However, in all probability the alluvium bottom accompanying the river is underlain by this formation, giving it a total thickness of slightly more than 100 feet.

Well borings from Quincy indicate that the thickness of the Chattahoochee formation at that locality is slightly greater than 100 feet; but here, as elsewhere, it is difficult to determine the exact thickness of formations from well samples. The maximum thickness of the formation is probably double the figure given above and it may even be as great as 250 feet.

Physiographic Expression::—In general, the region underlain by the Chattahoochee formation is one of high relief and well developed surface drainage. However, this is not always due to the character of the rocks of this group, for in the northern part of the State the surface configuration is often determined, in part, by the character of the superficial sands and clays of post-Oligocene age. The limestones of the Chattahoochee formation are less soluble than those of the underlying Vicksburg group; and, hence, they contain fewer underground streams, which give a characteristic sink-hole topography. However, underground streams, sink-holes and natural bridges are by no means rare. Where the limestones belonging to the Chattahoochee formation are thin the topography is often the combined result of solution of the Lower Oligocene limestones and the protection of the ridges and hills by the more durable Upper Oligocene limestones.

---

[1] Vaughan, T. Wayland. Unpublished notes.

Paleontologic Characters:—At some localities in southern Georgia the basal layers of the Chattahoochee formation supply many corals[1] and the lower part of this formation contains *Orthaulax pugnax,* a gastropod which is characteristic of the "silex bed" at Tampa. This locality has been studied by Vaughan,[2] whose description emphasizes the existence of an erosion interval between the deposition of the Vicksburg and Apalachicola groups, and shows the existence of a fossil coral reef. Of this coral reef, Vaughan says:

> My estimate is that there are between twenty-five and thirty species.
>
> This is the richest fossil coral fauna known from any one locality of the Continental North American Tertiaries. However, the state of preservation of the specimens is not always satisfactory, and it may not be possible specifically to describe all of them.
>
> The particular interest of this fauna does not lie in its richness, but in its geologic import. The Tertiary coral faunas of the United States below the Chipola horizon were very isolated, no species from the continent, excepting the *Orbicella* mentioned, being found in any other area. This fauna is distinctly Antiguan in types. Besides the *Orbicella* referred to, there is a very large-celled *Orbicella,* very close to *O. crassilamellata* (Duncan), if not identical with that species, found abundantly at Russell Spring. An *Astrocoenia* is extremely close to *A. ornata* of Duncan from Antigua. The same remark will apply to the *Stylophora* and *Alveopora.*
>
> From this field examination it appears that the reef corals of the Antiguan marls and cherts can be correlated with the base of the Chattahoochee limestone, the base of Dall's upper Oligocene. It is also quite probable that the Oligocene reefs in the vicinity of Lares, Porto Rico, and of Serro Colorado, Curacao, represent the same horizon. The Bowden, Jamaica, fauna would be slightly higher, to be correlated with the Chipola fauna.
>
> It is evident that this coral fauna from Russell Spring, besides filling a gap in the faunal succession on the continent, furnishes a basis for correlating many of the West Indian fossil reefs with the continental Tertiary section, and we may confidently expect more light upon the correlation of American and European horizons.

---

[1] Pumpelly, Raphael. An apparent time break between the Eocene and Chattahoochee Miocene in southwestern Georgia; Amer. Jour. Sci., 3rd ser., vol. xlvi, 1893, pp. 445-447. See Vaughan, Science 1900.

[2] Vaughan, T. Wayland. A Tertiary Coral Reef near Bainbridge, Georgia. Science, N. S., vol. xii, 1900, pp. 873-875.

One interesting feature of these corals, not already mentioned, is that they apparently bring the fauna of Vicksburg, Mississippi, into closer relation with the succeeding faunas. A great deal is shown regarding the succession and interrelations of the faunas of the continent itself.

A bed in the lower part of the Chattahoochee formation usually contains an abundance of *Echinoids*, and several different genera belonging to this group are known to occur in other horizons. At a horizon about twenty feet above the echinoid bed there is a layer containing an abundance of gastropods belonging to the genus *Helix*, and a slightly higher horizon is characterized by numerous specimens of *Cerithium*. Among the fossils collected from this limestone are:[1]

Pyrazisinus cornutus.
Cerithium hillsboroensis.
Potamides transecta.
Conus planiceps.
Natica amphora.
Lucina hillsboroensis.
Cardita serricosta.
Venus staminea.
V. cancellata.
V. penita.
Cytherea nuciformis.
Cyrena vesica.
Orbitolites floridanus.
Tagelus undet.
Solen undet.

Structure:—In northwestern Florida the limestones of the Chattahoochee formation dip toward the south. The exact amount of this dip is difficult to determine, but careful estimates by Miss Maury, based on sections made by Harris, places the average descent at twenty-three feet per mile. The same writer has noted a variation in the rate of dip, as will be seen from the following quotation:

> That this dip is steeper toward the north is shown by the following rate of slope:
>
> | | |
> |---|---|
> | Aspalaga to ravine | 1-8 mile, 10 feet, or 80 feet per mile. |
> | Aspalaga to Camp Scott | 2 miles, 70 feet, or 35 feet per mile. |
> | Camp Scott to Rock Bluff | 3 miles, 48 feet, or 16 feet per mile. |

Local Details:—The Chattahoochee formation, which is best exposed along the Apalachicola River, has been described by a number of writers. At Chattahoochee, according to Dall, the major portion of the rock exposed belongs to the Alum Bluff formation. His most complete section, which was made on the road running north from Chattahoochee Landing, is given below.[2]

---

[1] Dall, Wm. H., and Stanley-Brown, Joseph; Cenozoic geology along the Apalachicola River; Bull. Geol. Society of Amer., vol. v, p. 153, 1894.

[2] Dall, Wm. H. and Stanley-Brown, Joseph. Cenozoic geology along the Apalachicola River, Bull. Geol. Soc. of Amer., vol. v, 1894, p. 152.

Sections at Old Chattahoochee Landing.

		Feet.
1.	Reddish sand and gravel, with streaks of clay	20 to 40
2.	Grayish yellow friable marl, with harder layers	20
3.	Greenish clayey marl, very adhesive	2½
4.	Chattahoochee limestone, with fossil casts	4
5.	Talus to water's edge, about	3
	Total thickness	49½ to 69½

This section was taken on the road running northeast from the landing.

		Feet.
1.	Reddish sands, gravel and clays	15 to 20
2.	Grayish yellow marl, friable	20
3.	Greenish clayey marl, sticky	2½
4.	Talus to Water's edge, about	3
	Total thickness	30½ to 45½

Section number 2 was taken on the road which runs about southeast from the landing. The exposures are mostly in the gullies.

The fossil-bearing bed is number 4, and contains, among other fossils, echinoids, *Pecten* (Chipola sp.), *Arca* (like transversa), large solitary coral, *Venus penita, Lima* (like *scabra*), *Hemicardium, Ostrea, Loripes, Scala, Plicatula, Divaricella, Pyrazisinus, Phorus,* all as poor casts; fish bones and ribs of some mammal resembling those of the Manatee. No orbitolites were seen.

From the correlations made by Dall it is apparent that he regarded No. 1 of the above section as Lafayette and Nos. 2 and 3 as Alum Bluff. A generalized section made by Vaughan[1] from Chattahoochee Landing to Chattahoochee postoffice, is given below:

		Thickness.	
		Feet.	*Inches.*
3.	Red sands with some gravel. Toward the base becoming more argillaceous sometimes composed of mottled red sands and bluish or purplish clays. The basal portion forms a mantle following quite closely the contact with the Alum Bluff formation	50	
	The mottled basal portion extends through a vertical distance of about 40 feet.		
2.	White chalk and clays sometimes greenish or bluish. The greater portion of these clays are calcareous and a considerable portion is argillaceous limestone in harder and softer ledges. A calcareous specimen (chalky) was taken 70 feet above the water's edge of the river. The clays are jointed and show conchoidal exfoliation. The lower portion of this exposure does not appear to be calcareous. Some fine sands at the bottom. Thickness	50	
	Rocks of the same character, either clay or limestone, as that described above, occur 100 feet above the river. The		

---

[1] Vaughan, T. Wayland. Unpublished notes.

total thickness of the Chattahoochee formation here exposed is 80 feet.	
1. Alluvium of river bottom composed of reddish sands along the river, thickness	20
No exposure of beds beneath the river alluvium was seen.	
Total	120

In commenting upon this section, Vaughan says:

> It is evident that I did not examine the specific locality described by Dall, for I did not see *his* Chattahoochee limestone. The upper part of *his* No. 2 is the lower part of my No. 2. From Dall's description the whole of my No. 2 would be referable to the Alum Bluff. The combination of his section and mine gives a thickness of over 80 feet. His maximum thickness is 67 feet.

The following more detailed section by Vaughan shows the character of the rocks exposed in the lower part of the section given above.

	Feet.	*Inches.*
3. White argillaceous chalk in harder and softer layers	46	
2. Very calcareous blue clay	2	
1. Indurated calcareous clay stained yellow in places	15	3
Six feet 6 inches above the base is a fine-grained, very calcareous marl white or slightly tinged with yellow in spots. This stratum contains casts of many shells, etc.		
Total	63	3

At Wiley's Landing on the Chattahoochee River, about seven miles above River Junction, Vaughan obtained the section given below, but it has not been correlated with the other sections farther down the river.

Section of bluff at Wilcy's Landing.	*Thickness.*	
	Feet.	*Inches.*
7. Red clay	5 or 6	
6. Limestone	25	
5. Not definitely exposed, clay or limestone, probably limestone or calcareous clay	5	6
4. Limestone containing a large oyster, *Isocardia, Venus, Pyrula,* etc.	5	6
3. Unexposed surface red clay, apparently underlain by limestone		11
2. Bluish sticky clay	5	6
1. From water's edge to 5 feet 6 inches not definitely exposed, but apparently bluish sticky clay. There is much limestone detritus over the surface, it having rolled down from the upper part of the bluff. Thickness	5	6

The surface of this bluff is so covered by red clay and talus from above (limestone pebbles and boulders) that it is not possible to discover the details of the section. The basal 11 feet are argillaceous while the succeeding 47 feet are for the most part limestone. But the rock is so indurated that the fossils can scarcely be freed from the matrix. In one portion of the limestone horizon, the lower 25 feet, very large oyster shells are abundant. These weather out in good condition, probably because their matrix is argillaceous or because the limestone is softer. The greater portion of the limestone is hard and rings under blows of the hammer.

No fossils were found in the basal argillaceous layers. These lower layers would, according to the literature, probably be referred to the Vicksburg. The limestone belongs to the Chattahoochee. The lithologic specimen of it was taken from the top of the exposure and a fair number of fossils were collected. The exposure was also photographed. This section was measured by a hand-level.

The following descriptions were also furnished by Vaughan:

Section, Aspalaga Landing.	*Thickness.* *Feet.*	 *Inches.*
5. Sand	27	6
4. White lime rock. The surface appearance and color are those of chalk. This rock is indurated in thick, massive ledges and fragments show concentric exfoliation. Its color is originally bluish and becomes white upon drying.........	39	6
3. Chalky limestone more calcareous in the basal portion.......	18-20	
2. Friable limestone containing patches of blue clay and very poor remains of fossil mollusks..........................	1	4
1. Whitish tinged yellowish chalk which when kneaded in the water forms a whitish sticky paste. The stratum is sufficiently indurated to form a ledge and extends at least 1 foot below the surface of the water. Thickness........	7	8

The argillaceous basal portion of stratum No. 3 is about 2 feet, then follows a chalky stratum and bluish clays at the base of No. 4.

At the extreme upper end of the bluff the exposure is more satisfactory. The bluff face (Nos. 1, 2, and 3, and the lower 10 feet, 8 inches of No. 4, total thickness 30 feet 5 inches) is white chalk with layers of more or less friable and argillaceous marl. Fossils are very numerous and several layers of the chalk especially in stratum No. 2 and at the top of the bluff face, but all are miserably preserved, there being no shell substance left, only casts. *Nucula, Pecten, Venericardia, Lucina, Isocardia, Meretrix, Turritella, Stylophora* solitary corals, etc., were observed.

A resume of the exposure at Aspalaga excluding the surface sands, is as follows:

	Feet.	*Inches.*
4, ...	39	6
3, ...	11	
2, ...	1	4
1, ...	7	8
Total thickness	59	6

(Or roughly, 60 feet.)

The whole of these 60 feet (perhaps excepting some marl beds near the top) is chalky limestone. This section was measured with a hand-level.

I could not find the marl bed described by Dall and think it must have been simply a disintegrated chalky stratum or weathered chalk as the weathered chalk is frequently a clay marl. The limestone was sectioned at two places, one near the lower end of the bluff; the measurements were by hand level and steel tape; the uppermost exposure was a ledge and the thickness as has already been stated was 59 feet 6 inches, or roughly, 60 feet.

Near the upper end of the bluff an aneroid section was made and 55 feet was the thickness by that measurement, practically the same as the preceding.

Coming down the road to Aspalaga Landing is an exposure just before passing to the river bottom. To the right of the road is a small branch that empties into the Apalachicola at Aspalaga Landing. The Chattahoochee formation forms an escarpment a few feet high along the northern side of the branch. An aneroid measurement from the water's edge to the highest exposure on the road gave a thickness of 35 feet, that is, only a portion of the limestone is there exposed.

At the crossing of the River Junction-Bristol Road, over (Flat Creek?) is an exposure of limestone of small extent, probably the Chattahoochee.

Tests with acid of specimens from Aspalaga Bluff.

Stratum 4.	Specimens from highest exposure effervesces. Specimen from chalk ledge in face of bluff effervesces.
Stratum 3.	Clay, just beneath base of No. 4, considerable effervescence. Very calcareous, stiff blue clay effervesces strongly.
Stratum 2.	A friable limestone, containing considerable clay.
Stratum 1.	Is an argillaceous limestone, chalk.

Section western end of trestle east of River Junction, Mile-post 206.

			Thickness.	
			Feet.	*Inches*
(7.)	4.	Soil and humus	1	6
(6.)	3.	Gray sands	3	
(5.)	2.	Stiff, mottled sandy clay	3	
(4.)	1.	Stiff, non-calcareous blue clay	3	2
		Total	10	8

(Section measured with steel tape.)

Immediately below (4) 1, of the preceding section and nearer the Creek.

		Thickness.	
		Feet.	*Inches.*
3.	Sandy, ferruginous clays containing black, apparently carbonaceous particles. Stratum mottled yellowish or brown, and bluish white with black spots	3	
2.	Stiff blue clay with lumps or seams of white clay	1	
1.	White, sandy, non-calcareous clay oxidizing yellowish or brown on surface	3	6

The barometer readings correlate these clays in altitude with those immediately back of the station house at River Junction and as they are similiar in character this correlation is apparently trustworthy.

One telegraph pole west of milepost 205 is an exposure of the argillaceous chalk of the Chattahoochee 2.7 feet in thickness. It is overlain by the dump from the railroad excavation. The material was tested with acid and found to be calcareous. It has the appearance of the usual limestone of the Chattahoochee

The surface shows irregular joints and conchoidal or concentric exfoliation. One imperfect fossil was found, a surface cast, probably a *Lucina.*

This locality is about 2½ miles east of River Junction railroad station on the Seaboard Air Line Railway. River Junction is at mile-post 208, 208 miles from Jacksonville.

From looking along the railroad this exposure seems to be topographically lower than the two preceding exposures.

Excepting the two exposures described, there are none between this locality and River Junction excepting surficial sands and may be some red sands or clays and sands. There are no deep cuttings along the railroad track.

Section at Station House, River Junction.	*Thickness.* Feet.	Inches.
Chocolate or brownish soil	1	
Sandy whitish clay	1	6
Sandy whitish clay slightly calcareous in ledges	8	
Total	10	6

Section near lower end of train yard.	*Feet.*	*Inches.*
7. Humus and blackish or dark brown soil, about	1	
6. Yellow sandy clay or marl, estimated	3	
5. Whitish sandy clay, very slightly calcareous	4	7
4. Whitish sandy clay (very slightly or not at all calcareous)	4	
3. More calcareous white sandy clay	1	
2. Very calcareous sandy clay	1	5
1. Sandy chalk very argillaceous, sand grains fine	6	5
Total	21	7

1, at edge of sand flat of small branch. This last bed is the one from which Dall mentioned fossils. I found as poor casts, *Isocardia, Hemicardium, Venericardium, Tagelus, Turritella* (very large species) cast of inside of large gastropod (*Orthaulax?*), smaller gastropods, etc. There were many specimens and many species but all poorly preserved.

Between River Junction and the railroad bridge over the Apalachicola River, there are no rock exposures except the one already mentioned.

Ditch running east from back of Station House at River Junction.

A few yards east of the wagon road crossing the railroad there is a small fall in this ditch and here a number of fossils were obtained:

Mammalian ribs, fragments. (These ribs are probably of the manatee.)
Large Chelepod crustacean claws, the animal apparently the size of a large lobster.
Cardium, several species.
Hemicardium.
Venericardia.
Pecten.
Venus.
Lucina.
Astarte.
Natica (very large species).
Orthaulax?
Fusus.
Cerithium or Turritella.

The shells are all casts, internal or external, but the fauna is evidently typical Chattahoochee. One fine regular Echinoid was collected.

	Cement Quarry one-half mile south of River Junction.	*Thickness.* *Feet.*	*Inches.*
8.	Superficial coating of black humus and some gray sand......		
7.	Friable chalky limestone forming slope of hill...............	13+	
6.	Harder chalky layer		5
5.	Softer chalky layer	1	5
4.	Harder, somewhat saccharoidal limestone..................		9
3.	Softer fossiliferous chalk	1	7
2.	Harder limestone with numerous fossils, the commonest the *Hemicardium* and an orbitoid foraminifer. This material when weathered turns reddish and forms a residual red clay. No original molluscan tests were observed, but they are sometimes replaced by crystalline calcite............	1	3
1.	Soft white chalk, indurating upon exposure, used in making cement brick	4	

According to the barometer, the base of No. 1 is 50 feet above the railroad at River Junction.

Some twelve to fifteen feet of limestone belonging to the Chattahoochee formation is exposed at Rock Bluff, and it doubtless underlies the Chipola marl member at Alum Bluff. On the Chipola River the same limestone is exposed at intervals from near the mouth of Ten-mile Creek northward to beyond the Peacock Bridge. These exposures seldom exceed four or five feet in thickness and the rock is a chalky limestone similar to that exposed on Apalachicola River. The outcrops at Peacock and Willis bridges on the Chipola River were visited, but they proved to be nearly destitute of organic remains. This limestone, doubtless, forms the natural bridges over Ten-mile and Sinking Creeks, tributaries of the Chipola River, but high water prevented a close examination of these localities. Similar limestone occurs in the form of loose bowlders in the vicinity of Knoxhill, Walton County, and outcrops of it are reported on the Choctawhatchee River, south of the Louisville and Nashville Railroad bridge. At Caryville, the well of the Wood Lumber Company penetrated eight feet of pinkish limestone, which doubtless belongs to the Chattahoochee formation. The limestone at St. Marks and at some localities farther north and east is also tentatively referred to this formation.

TAMPA FORMATION.

The Tampa formation consists of greenish clays, light gray to yellow limestones, and a very fossiliferous bed of "silex." Hitherto, the "silex" and a portion of the limestone have been all that was known of the formation. The "silex beds" and limestone of the Tampa formation were first examined by Conrad[1] over sixty years ago. In the same year Professor Allen[1] described both the limestone and "silex bed" at Tampa, and his account of these beds has been generally accepted as correct. The same locality was subsequently visited by Tuomey.[2] In 1884, Kerr and Mitchell[3] visited Tampa and noted the replacement of fossiliferous limestone by chalcedony in what has since been called the "silex bed." Ballast Point, near Tampa, where the "silex bed" is best exposed, is the locality where Bailey[4] found, what he regarded as infusorial earth, resting on the "silex bed." Later investigations have shown that this material is merely a residual material produced by the action of the weather upon the silicified limestone.

---

[1] Conrad, T. A., Observations on Eocene formations and descriptions of 105 new fossils of that period from the vicinity of Vicksburg, Miss.; Phila. Acad. Science Proc., vol. iii, p. 28.

In 1887, Heilprin[5] published an account of the explorations near Tampa and called attention to the fact that the fossil which Conrad regarded as a nummulite is really an orbitulite. Heilprin gave a brief description of Ballast Point and other exposures near Tampa, but does not appear to have recognized the relations between the limestone and the "silex bed." Later publications by Dall give more complete descriptions of the Tampa exposures and show clearly that there are two horizons represented which he has called respectively "Tampa silex bed" and "Tampa limestone." Because the "silex bed" is characterized by the presence of *Orthaulax pugnax,* Dall has called it the "*Orthaulax* bed" and the limestone has been designated "*Cerithium*[6] rock," on acount of the presence of many specimens belonging to that genus.

In his bulletin on the Neocene of North America, Dall[7] described the "Tampa group," including what he designates the Tampa, Chipola and Alum Bluff beds. But the subsequent discovery of *Orthaulax pugnax* in the Chattahoochee led him to place the "silex beds" in his "Chattahoochee group."[8]

While engaged in the field work for this report, additional information concerning the rocks at Tampa was obtained. Stated briefly, the observations showed the presence of a limestone below the "silex bed" and the existence of clay beds at both the base and top of the formation. The limestone below the "silex bed" is similar to what Dall[1] has called "*Cerithium* rock," and in this connection it is interesting to note what he has said concerning its existence:

---

[1] Allen, Prof. John H. Amer. Jour. Sci., 2nd ser., vol. ii, 1846, pp. 36-48.

[2] Tuomey, M. Notice on the geology of the Florida Keys and the southern coast of Florida. Am. Jour. Sci., 2nd ser., vol. ii, 1851, pp. 390-394.

[3] Kerr, W. C., and Mitchell, Elisha. Scientific Society, 1884-5, p. 87.

[4] Bailey, J. W. Microscopic Observations, Smithsonian contributions to knowledge, vol. ii, No. 8, 1850, p. 19.

[5] Heilprin, Angelo. Explorations on west coast of Florida; Wagner Free Institute of Science Trans., vol. i, 1887, pp. 10 and 11.

[6] Dall, Wm. H. Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, pp. 112-113.

[7] Loc. cit.

[8] Dall, Wm. H. Tertiary fauna of Florida; Wagner Free Institute of Science Trans., vol. 3, pt. 6, 1893, pp. 1564 and 1565.

> From these observations it appears that, while the existence of a *Cerithium* rock under the *Orthaulax* bed is a priori probable, sufficient evidence of its existence is still to be collected, and the rock identified as such by Heilprin may very possibly have been a portion of the Tampa limestone.

Since the publication of the report from which this quotation is taken, a series of wells have been drilled, and the samples which were preserved show the presence of the limestone below the silex.

Stratigraphic Position:—Evidence of an unconformity at the base of the Tampa formation was obtained in drilling wells for the city of Tampa. The log of one of these wells is given on page 89, and it will be noted that after passing through thirty feet of limestone and chert the drill encountered a blue clay forty-one feet in thickness. The limestone and chert represent the limestone and "silex bed" of the Tampa formation and the clay appears to belong at the base of that formation. At a distance of 200 feet from the well mentioned above, the clay was encountered at about the same depth and was said to have a thickness of sixty-four feet. This variation shows that the underlying limestones of the Vicksburg group have an irregular surface which was doubtless produced by erosion.

The relation of the Tampa formation to the Hawthorne and Chattahoochee formations has already been discussed, and its stratigraphic relation to the Alum Bluff formation is probably similar to that of the other two formations mentioned. The post-Oligocene formations, which occur in the area where the Tampa formation is known, rest unconformably upon it.

Lithologic Character:—The upper member of the Tampa formation comprises a well stratified greenish clay containing some calcareous nodules and thin beds of limestone near the base. Scattered throughout the clay are many silicified corals, some of them having a diameter of two or three feet. The clay is very plastic and hence is valuable for the manufacture of brick. Beneath this clay is the light-gray to yellow limestone which was formerly called the "Tampa limestone." The "silex bed" represents a silicified zone in this limestone and is, therefore, a zone of replacement. This is well shown by some of the fossils which have been only partially silicified; and by the presence of more or less unaltered carbonate of lime in the original rock. Small nodules of chert occur at other horizons in the limestone, and outcrops of the rock are often denser and harder than exposures in quarries. Locally the limestone is hard enough to make a durable building stone which might be useful in the construction of foundations for buildings. Fossils are abundant in some parts of the limestone, but they are largely represented by casts and molds, which have been left by the solution of the original shells. The "silex bed" contains numerous fossils which have been wholly or partially replaced by chalcedony. Resting upon the "silex" at some localities is a siliceous residual material which was formerly thought to be infusorial earth, but is now known to be weathered material derived from the underlying rock. In such cases the action of the percolating water has removed the matrix, leaving many beautifully preserved pseudomorps and casts of shells. These fossils are commonly composed of chalcedony which frequently exhibit the characteristic markings of the original shells. (See Fig. 2, Plate IV.)

---

[1] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, p. 119.

Beneath the limestone beds is a greenish clay which commonly contains a considerable admixture of sand. This clay is very plastic and resembles the clay which overlies the limestone. Judging from well records, the deposit is homogeneous, but there is a possibility that the sand contained in the well samples may be derived from thin sand partings in the clay bed.

Thickness: — The information concerning the thickness of the Tampa formation is meager, but it is sufficient to fix the maximum thickness at more than 130 feet. The clay bed at the top of the formation has a known thickness of fifteen feet. The limestone between the "silex bed" and the upper clay is about forty feet thick. The thickness of the "silex bed" varies considerably, ranging from about four feet to more than ten feet. Beneath the "silex bed" is a limestone which has a known thickness of six feet. The clay bed at the base of the formation has been penetrated by two wells within 200 feet of each other, and the thickness varied from forty-one feet to sixty-four feet.

Physiographic Expression: — The area underlain by the Tampa formation is so near sea level that no marked physiographic features can be discerned. The influence of the limestone of this formation is seen in the rapids of the Hillsboro River; and it may be the solution of these limestones which gives rise to some of the depressions northeast of Tampa. Aside from these minor features, the surface of the formation is not very diversified.

Paleontologic Characters:—In addition to the characteristic *Orthaulax pugnax,* the "silex bed" of the Tampa formation has furnished a very large number of species, including some corals, many species of gastropods, pelecypods and a few specimens of *Orbitolites floridanus* which becomes abundant in the overlying limestone. At

Ballast Point the fauna of the "silex bed," though largely marine, contains many fresh water shells which were probably supplied from some lakes or lagoons situated near the shore. The complete list of the fossils from the "silex bed" is given by Dall, who says:[1]

> About forty-nine per cent of the species in the *Orthaulax* bed are peculiar to it, and very few of the more minute forms which should be present in such a fauna are known. The relations of the fauna are most intimate with that of the Oligocene beds above it, the Orbitolite or Tampa limestone, the Chipola, and the Oak Grove sands. With either of these the percentage of species common to both is more than twice as great as with any of the beds below, such as the nummulitic, the Peninsular limestone, or the Vicksburg. But it must be admitted that the faunas of all these, except the last, are very imperfectly known. With the faunas of the horizons above the Oak Grove sands, there is little in common, though in the tropical waters of the Antilles, about eight per cent of the species are believed to survive to the present day. Only about 2.6 per cent survive except in tropical waters.
>
> One of the most interesting features of the fauna is the assembly of land shells, which are southern immigrants and have left no survivors on the American continent at the present day, though representative species occur to the southward.

The fauna of the limestone in the Tampa formation contains fewer species than that of the "silex bed," but the faunas are closely related, as will be seen by the following quotation which contains Dall's comments on the list of fossils from these two beds:[2]

> Total, ninety-five species, of which thirty-six are uncertain specifically, leaving fifty-nine identified, of which thirty-seven are common to the silex beds, ten are peculiar to the Tampa limestone horizon, four are known from the Ocala nummulitic limestone, and two appear in the Vicksburgian, the Jacksonian, and the Claibornian. One species (and probably more not yet discriminated) survives into the Chipola and two are believed to persist to the recent fauna.

Structure:—The Tampa formation lies near sea level and hence it is difficult to get sections which show the structure of the beds. Apparently the formation is nearly horizontal with a slight seaward dip. While the formation may be affected by gentle flexures, the evidence is still too meager to show their existence.

Local Details:—The "silex bed" of the Tampa formation is best exposed at Ballast Point where it rises only a few feet above tide. At this locality the maximum thickness of the bed is not shown. Dall's[3] section at Tampa is:

---

[1] Dall, Wm. H., Geological results of the study of the Tertiary fauna of Florida; Ex. from Trans. Wagner Free Institute of Science, Phila., vol. iii, Part vi, p. 1565, 1903.

[2] Ibid, p. 1572.

[3] Dall, Wm. H. Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, p. 113.

White sand	6 to 24 inches.
Yellow sand	6 to 36 inches.
Pliocene breccia	traces.
Tampa limestone	10 to 15 feet.
Tampa silex bed	6 to 10 feet.

In drilling wells at the Tampa water works, between Sixth and Seventh avenues, the "silex bed" was found to have a thickness of only four feet. Beneath the "silex bed" there was a thin bed of limestone underlain by greenish clay, which varied in thickness from forty-one to sixty-four feet. The log of one of these wells follows:

1.	White Pleistocene sand	2 feet.
2.	Tough yellow clay with no sand, residual clay	10 feet.
3.	Soft limestone which disintegrates readily—"Tampa limestone"	14 feet.
4.	Chert, "Tampa silex bed"	4 feet.
5.	Soft limestone closely resembling No. 3	6 feet.
6.	Tough plastic greenish sandy clay	41 feet.
	Base of the Tampa formation:	
7.	Chert	2 feet.
8.	White marl	6 feet.
9.	Soft limestone	6 feet.
10.	Very light colored hard rock	15 feet.
11.	Very hard dark yellow limestone	6 feet.
12.	Gray porous limestone with some water	15 feet.
13.	Cherty beds	14 feet.
14.	Darker limestone.	
15.	Gray plastic clay.	
16.	Hard yellow rock with chert.	
17.	Gray porous rock, water-bearing.	
18.	Like preceding.	

Nos. 3-6 inclusive represent the Tampa formation, but at this locality the upper clay and a portion of the limestone have been removed by erosion.

Another well 200 feet away encountered sixty-four feet of No. 6, which suggests an unconformity at base of this bed, and this hypothesis is strengthened by the fact that the rock immediately below the clay differed in the two wells.

The upper clay bed of the Tampa formation is best exposed at the pit of the Tampa Brick Company on the bank of the Hillsboro River five miles northeast of the city. At this locality there is an exposure of from ten to fourteen feet of light green siliceous clay which is unconformably overlain by from two to four feet of light-gray Pleistocene sand. The clay is very plastic and is said to make excellent brick. Scattered throughout the deposit are numerous cobbles and boulders of chert which represent silicified corals. While the major portion of the exposure is of a light greenish color toward the bottom of the pit, the clay becomes gray and is interbedded with thin nodular layers of limestone.

A light green siliceous clay similar to that described above was seen on the west side of Old Tampa Bay, near Safety Harbor (Espiritu Santo Springs). Here the section shows four to six feet of white Pleistocene sand resting unconformably upon six feet of greenish clay. On the beach, near this exposure are several large chert boulders which were probably derived from beds beneath the clay. About one mile north of the postoffice the following section was observed:

White Pleistocene sand	2-4 feet.
Dark brown sand, partially indurated	1-6 feet.
Light greenish clay, thinly laminated	5 feet.

On the Gulf coast, near Clearwater, are numerous exposures of cherty limestone which are probably to be correlated with the rocks at Tampa, but in the absence of paleontologic evidence, this correlation must be regarded as merely tentative. A generalized section at this locality was obtained from well records and observations along the beach.

1.	White Pleistocene sand	12 feet.
2.	Light colored clay	14 feet.
3.	Light colored limestone with chert concretions	1 ft. to 6 in.
4.	Bluish laminated marly clay with chert concretions	2-4 feet.
5.	Light gray limestone with chert concretions	2-3 feet.

A generalized section near Laporitieres Spring is given by Dall:[1]

Humus, yellow sand, etc.	6 to 36 inches.
Tampa limestone	10 to 15 feet.
Orthaulax bed	7 in. to 10 ft.

The limestone of the Tampa formation is exposed near the pumping station, where it has been quarried to a depth of over fifteen feet, and other exposures occur at intervals along the Hillsboro River for a distance of over fifteen miles inland. Probably the best exposures are in the excavations near the Sulphur Spring, northeast of Tampa, and at the rapids about a mile above the spring. The same limestone was observed resting on the "silex bed" at the railroad crossing over Six-Mile Creek. Here the limestone is immediately overlain by fossiliferous Pleistocene shell marl which grades upward into coarse white sand.

Section one-eighth mile below railroad bridge—Orient (*Tampa*).

4.	Soft white marl	6 feet.
3.	Light gray to buff fine grained quartz sand	3 feet.
2.	Gray shell marl Pleistocene	1-2 feet.
1.	White soft limestone with some gastropods and other fossils	5 feet.

---

[1] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, p. 108.

No. 2 rests unconformably upon No. 1 and is a thin but persistent bed.

Section at railroad bridge—Orient (Tampa).

5.	Fossiliferous white sand	2 feet.
4.	White marl	6 feet.
3.	Light gray sand	1 foot
2.	Gray shell marl	0-1 foot
1.	Gray to yellow limestone, very fossiliferous in places	6 feet.

No. 2 rests unconformably upon No. 1 and is evidently the same horizon as No. 2 in the preceding section. The limestone in both of these sections is what has commonly been called "Tampa limestone." In the section at the railroad bridge, there is some "silex" near the base and this evidently represents the same horizon as the "silex bed" at Ballast Point.

ALUM BLUFF FORMATION.

The name Alum Bluff formation as here used includes those beds which belong stratigraphically between either the Chattahoochee formation or the Hawthorne formation and the marls and limestones of Miocene age. This usage differs from that of Dall,[1] who appears to have regarded the Chipola marl and the Alum Bluff as distinct formations. The Alum Bluff formation includes two different, though closely related, members which have been known respectively as the Chipola marl and the Oak Grove sands. To these is added a third member, recently discovered by Vaughan[2] in west Florida, and called the Shoal River marl member, from the stream where it is best exposed. The Chipola marl member and the sands of the type locality at Alum Bluff were first described by Langdon, who referred them to the Miocene.[3]

The type locality of the Chipola[4] marl member is at McClelland's farm, near Bailey's Ferry, on the Chipola River, and the Alum Bluff formation is named from a bluff on the Apalachicola River, where it was first examined. The fullers earth deposits which represent the Alum Bluff formation east of the Apalachicola River, have been mentioned by a number of writers, but the first comprehensive description of them was given by Vaughan[1] in 1901. The Oak Grove sand member was described by Dall[2] in 1893.

---

[1] Dall, Wm. H., Cenozoic Geology Along the Apalachicola River; Geol. Soc. Am. Bull., vol. v, 1893, p. 167.

[2] Vaughan, T. Wayland. Unpublished notes.

[3] Langdon, Daniel W., Jr. Some Florida Miocene; Am. Jour. Sci., 2nd ser., vol. xxxviii, 1889, p. 32.

[4] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey Bull. No. 84, 1893, p. 122.

Exposures of limestone on the Sopchoppy and Ocklocknee Rivers, some five or six miles from the town of Sopchoppy, have been called the "Sopchoppy limestone." This rock was first described by Dall[3] who assigned it to about the horizon of the Chipola marl member. In this report it is tentatively included with the Alum Bluff formation. Further investigation is needed to determine its exact stratigraphic relations.

The limestones and marls on the Manatee River near Ellenton were thought by Heilprin[4] to belong to the Miocene, but are probably somewhat older. They are here referred tentatively to the Oak Grove sand member of the Alum Bluff formation, but this correlation is subject to revision, if subsequent investigations should show that the fauna is characteristic of some other horizon.

Stratigraphic Position:—The Alum Bluff formation is conformable upon both the Chattahoochee and the Hawthorne formations. This is inferred from the facts that no distinct evidence of a stratigraphic break between the two groups has been noted, and their faunas are closely related. At Alum Bluff, on the Apalachicola River, and Jackson's Bluff, on the Ocklocknee River, the marls of Miocene age rest upon an eroded surface of the Alum Bluff formation, but farther west, in Walton County, it is possible that they may be conformable.

Lithologic Character: — The Alum Bluff formation consists of marl, sand and clay, which are sometimes fairly distinct, but more often interbedded. Limestones also occur in the formation, but they are not extensively developed and usually contain enough earthy material mixed with the carbonate of lime to form marls. Shell marls with a calcareous or sandy matrix are common and they often occur interbedded with nearly pure sand. In general, the beds belonging to this formation are light gray, but occasionally shades of green or yellow prevail.

At Alum Bluff, on the Apalachicola River, Dall[5] gives the following section:

---

[1] Vaughan, T. Wayland. Fuller's earth; U. S. Geol. Survey, Mineral Resources of the United States, 1901, pp. 921-934.

[2] Dall, Wm. H. Cenozoic Geology Along the Apalachicola River, Geol. Soc. Am. Bull., vol. v, 1893, pp. 166-167.

[3] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. No. 84, 1892, pp. 119-120.

[4] Heilprin, Angelo. Explorations on the west coast of Florida. Wagner Free Inst., Trans., vol. 1, p. 13.

[5] Dall, Wm. H., Geol. Soc. Am., vol. v, 1893, p. 157.

1.	Superficial sands	8½ feet.
2.	Red clay	2½ feet.
3.	Reddish and yellowish streaked sands	66 feet.
4.	Aluminous clay	24 feet.
5.	Chesapeake gray marl	35 feet.
6.	Alum Bluff sands with streaks of clay	21½ feet.
7.	Hard Chipola marl to water (variable)	3¼ feet.
	Total thickness above water	160¾ feet.

The composition in detail of these several beds is as follows:

Number 1—Pale yellowish gray incoherent sand.

Number 2—Hard reddish clay weathering with vertical face.

Number 3—Streaky yellowish and reddish sands with small little-worn gravel, of siliceous character, mixed with it. Near the lower third a few obscure impressions, possibly representing fossils, were observed by Stanley-Brown. The lower 3 feet of the sand is more or less loamy from admixture with underlying clay. They are distinctly stratified in conformity with the other beds of the bluff.

Number 4—Tough gray aluminous clay weathering nearly vertical with a few fragments of vegetable matter in it and some obscure indications of gastropod and bivalve fossils, the shells entirely dissolved and represented chiefly by color-marks in the clay. The appellation of "lignitic," heretofore applied to this clay on the authority of Mr. Johnson, can not be regarded as justified, as the amount of phytogene material is trifling. The fossils may have been marine or fresh water. No satisfactory evidence is afforded by their faint traces, as observed by us.

Number 5—Bluish gray tough clayey marl replete with characteristic Chesapeake fossils, especially *Mactra congesta*. The upper six inches is discolored by iron oxide, derived from the water oozing from the bed above, which has also dissolved the shells, leaving only cavities. Toward the north, at a point (C. of figure 2[1]) near the camp the Chesapeake is thinned to 5 or 6 feet in thickness.

Numbers 6 and 7—The Chipola marl is compact and of a dark-reddish color from hydrated peroxide of iron contained in it. The fossils which are abundant are rather soft. Orthaulax is the most common shell; there are no traces of Orbitolites. The matrix is chiefly sand mixed with clay. At least 6 or 8 feet of the Chipola is below the water; it rises at the lowest stage of the river from 3 to 11 feet above the water's edge, weathering almost like a rock. There is no well defined line of separation between the marl and the Alum Bluff sands (number 6) above it, but the change takes place in a space of 5 feet, the lower portion of the sands containing more or less of the Chipola fauna. Above this they are mottled, bright ferruginous and yellow, and exhibit distinct marks of cross bedding. They contain sheets—laminae or lenticular streaks of clay—which show abundant leaf remains resembling willows and other water-loving plants, while the sands in the lower part of the bed contain large leaves and stalks of palmetto or other palm-like vegetation, the thicker parts of which are reduced to the condition of lignite. These are too friable to remove without previous hardening applied in situ. The upper part of these sands did not show any fossil remains at the points where we examined them.

---

[1] Not published in this report, see original paper.

Toward the north, where the bluff is much lower and the Chesapeake thinned out to 5 or 6 feet in thickness, the sands below it are unfossiliferous and modified. The upper part is more exclusively sandy, and, lower down, the bed assumes the clayey compact greenish color of the oyster marl at Rock bluff, a few miles above, but here the green marl contained no fossils.

The typical Alum Bluff formation consists of coarse, light-greenish gray to white argillaceous sands, often showing cross-bedding and usually containing more or less interbedded clay and fullers earth. One of the most characteristic features of the sands is the presence of innumerable flakes of white mica—the "isinglass" of the well diggers. The change from the shell marls of the Chipola marl member is by a transition zone which contains some of the same species of shells which characterize the marls. This zone also contains nodules of calcium carbonate which often enclose fossils. The upper part of the sands is usually free from shells, but occasionally contains impressions of leaves and fragments of plants. Locally, the Alum Bluff formation contains some clay, and near Chattahoochee it consists of greenish, sticky marl.

The fullers earth has the appearance of a dense, hard, fine-grained siliceous clay. It is thinly laminated, and commonly light gray to greenish in color. Sand partings sometimes occur, but they are comparatively rare, the material usually being homogeneous. Beds of sand and clay are commonly associated with the fullers earth, the sections consisting of interbedded sand and clay.

Thickness:—The aggregate thickness of the Alum Bluff formation is at least 135 feet, but the maximum thickness of a single section is scarcely one-half that amount. It is doubtful if the total thickness is represented in any single section. The thickness of the sands of the Alum Bluff formation at the type locality is about twenty to twenty-five feet, but farther north at Rock Bluff, Dall[1] reports a maximum of sixty-three feet. The fullers earth commonly occurs in beds of two to ten feet in thickness associated with several feet of clay and sand or sandstone. In some places two or more beds occur in the same section, separated by beds of sand and clay. The maximum observed thickness of fullers earth in a single section is about fifteen feet, and the aggregate thickness of the associated clays and sand which appear to belong to the same horizon is not less than twenty feet.

Physiographic Expression: — The members of the Alum Bluff formation, with the exception of the Chipola marl member, exercise an influence on the topography of the northern part of the State. They are soft and easily eroded into deep valleys but are sufficiently resistant to form steep slopes. Thus the region where the Alum Bluff formation lies near the surface is characterized by a topography which has been formed by surface erosion and which is in marked contrast to the sink hole topography of the central part of the peninsula. However, wherever this formation is thin, solution has given rise to many sink holes; and the topography is a composite of valleys and poorly drained depressions.

---

[1] Dall, Wm. H., and Stanley-Brown, Joseph. Cenozoic Geology along the Apalachicola River, Geol. Soc. Am., Bull., vol. v, 1893, p. 166.

Paleontologic Characters:—As already noted, the typical sands of the Alum Bluff formation are sparingly fossiliferous, the lower part containing a fauna allied to the underlying Chipola marl member, and the upper part being characterized by plant remains. The fullers earth beds contain a very poorly preserved fauna, from which Vaughan[1] secured enough material to show that they belonged to the Alum Bluff formation. He also notes the fact that these beds contain *Carolia floridana* Dall, which is characteristic of the Apalachicola group. Both the Oak Grove sand member and the Shoal River marl member are very fossiliferous.

Structure: — The Alum Bluff formation shows no marked peculiarities of structure. While it has undoubtedly been affected by some of the movements which produced the general arching of the strata, the disturbance has not produced any effect, except to give a general seaward dip to the beds. If any local deformation has produced folding of the beds belonging to the Alum Bluff formation, the existence of the folds has not yet been detected.[2] However, this may be due to the imperfect exposures.

Local Details:—Micaceous white sands belonging to this formation are well exposed on Ten-Mile Creek, at Carr's Mill, in Calhoun County, and at intervals for about one mile farther up stream. Here they consist of coarse light-gray sands containing many flakes of silvery white mica. Upon weathering, the sand changes to a pale yellow color from the presence of hydrated iron oxide. The sands show some evidence of cross bedding and appear to be destitute of organic remains. Similar sands are reported in wells farther west in Walton County, and exposures were noted beneath the Shoal River marl member near Knoxhill, Walton County.

Vaughan's[3] investigations have shown that the fullers earth beds are the stratigraphic equivalent of the sands at Alum Bluff. About four miles southeast of River Junction, at an abandoned fullers earth mine belonging to Mr. Hymeson, Vaughan reports the following section.[1]

---

[1] Vaughan, T. Wayland. Unpublished notes.

[2] See, however, structure of fullers earth strata in paper on fullers earth.

[3] Vaughan, T. Wayland. Fullers earth, U. S. Geol. Survey, Mineral Resources of the United States, 1901, pp. 926-927.

4.	Surface sands, beneath which are reddish sands containing some quartz gravel	60 feet.
3.	Stiff blue clay, the top of the fullers earth deposit	4 feet.
2.	Fullers earth. A considerable amount of the overburden had been thrown off, but due to weathering and wash there is really no good exposure. Judging from what can now be seen, according to a roughly leveled section, it seems that the deposit is at least 8 feet thick, and it may be thicker. There is no means of determining its horizontal extent. A box of the earth was collected from the best exposure.	
1.	Immediately beneath the fullers earth, there appears to be a deposit of sandy, very stiff blue clay. Thickness unknown.	

The following is the generalized section, according to aneroid readings made in the vicinity of River Junction :

Generalized section near River Junction.

Surface sands	60 feet.
Clay and fullers earth	10 feet.
Not exposed, but probably argillaceous sands	17 feet.
Chalk or limestone with some layers of marl (Chattahoochee), about	88 feet.

The rocks beneath the Chattahoochee formation are not exposed near River Junction.

The inference from this section apparently would be that the Chattahoochee formation is 88+ feet in thickness, separated by 17 feet of unexposed strata from the deposit of fullers earth, which would come above. This would stratigraphically correlate the deposit of fullers earth with the Alum Bluff formation.

The following is the detailed description and section of Rock bluff on the Apalachicola River published by Dall and Stanley-Brown.[2] The writer is of the opinion that the fullers earth horizon corresponds to No. 3 of their section.

The lower part of the bluff formed by the Chattahoochee limestone is vertical, rising 12 feet above the water, and presumably nearly as much below it, at low stages of the river. Above this is a mass of marl varying from bluish green to gray in color, weathering white, more arenaceous below and more marly above, replete with oyster shells, a fine, large *Anomia,* a pecten, like young *madisonius* (but, as observed by Foerste, only four-sevenths the size of that species; it is really a Chipola species), *Turritella,* and many *Balani.* This assemblage of species indicates a shallow water oyster-reef fauna unquestionably belonging to the "old Miocene" (Apalachicola group) and forming the shoal-water equivalent of the Chipola and Alum Bluff beds, especially the latter. Above this marl lie the red Lafayette clays and gravels—in this case worked-over materials—variable in thickness, owing to denudation, but apparently averaging about fifteen feet, and covered with a thin layer of superficial soil and sand. This section was carefully measured with a steel tapeline, due allowance being made for the inclination of the tape from the vertical. It shows the finest and thickest section of the greenish marl exposed anywhere on the river. The contact of the marl with the Chattahoochee limestone is distinct and without apparent unconformity or transition beds of any kind.

---

[1] Ibid. pp. 926-927.

[2] Bull. Geol. Soc. Amer., vol. v, 1894, pp. 155-156.

This section was measured on the highest part of the bluff, which is the first approached as the turn of the river is made in descending:

Section of Rock Bluff, Apalachicola River, Florida.

1.	Superficial sands, thin and variable, say	3 feet.
2.	Reddish clayey sand and gravel, about	15 feet.
3.	Greenish-white compact marl, with fossils	67 feet.
4	Chattahoochee limestone, to water	12 feet.
	Total thickness above water	97 feet.

The list of fossils given under the head of paleontologic characters indicates the correctness of the conclusions reached on the basis of purely stratigraphic work, for they show that the fullers earth beds are to be correlated with the Alum Bluff formation.[1]

About 1900 the fullers earth deposits of northern Florida were investigated by Vaughan,[2] and the results of his studies were published in the volume on Mineral Resources of the United States for 1901. The sections given below are taken from this report:[3]

Mosquito Creek.—There is an exposure of fuller's earth on the south bank of Mosquito Creek, near the foot of a bluff, on land belonging to Mr. John D. McPhaul. The overburden is here too great for working. The deposit is along a small stream running north into Mosquito Creek in the NW. ¼ of Sec. 16, T. 3 N., R. 4 W. A sample was taken at this locality where a pit had been sunk.

A section in the pit shows overburden (sand), 4 feet; fuller's earth, 6 feet. The bed was not completely penetrated.

The material was also exposed in the bed of a creek nearby. The slope down to the creek valley is gradual. A strip several hundred yards wide and probably half a mile long could be worked. Fullers earth occurs also on the land of Mr. A. J. Key, in Sec. 15, T. 3 N., R. 4 W.; and on the land of Mr. Elias Howell, in Sec. 10, T. 3 N., R. 4 W., and extends also along the creek about one-half mile below Mr. McPhaul's.

Near Quincy.—The following is a section through the fullers earth at the Chesebrough Manufacturing Company's mine, 1 mile south of Quincy. The section was given by T. L. Ward.

Section of Chesebrough Manufacturing Company's Mine.

5.	Overburden of clay and sands	7 feet.
4.	Fullers earth (average)	4 feet.

---

[1] A section made since the above was written by E. H. Sellards and Herman Gunter, published in the following paper on fullers earth deposits shows that the fullers earth stratum at Rock Bluff lies immediately above the gray sand or marl of the above section and at a level approximately 100 feet above the river.

[2] Vaughan, T. Wayland. Fuller's earth, Mineral Resources of the United States, U. S. Geol. Survey, 1901, pp. 926-932.

[3] Vaughan T. Wayland. Mineral Resources of the United States, U. S. Geol. Survey, 1901, pp. 928-929.

3.	White argillaceous sandstone containing fossils	5 feet.
2.	Fullers earth	9 feet.
1.	Soft sandstone, sand, and fullers earth	15 feet.

It is estimated that there are about 10,000 tons to the acre. The mine was visited in company with Mr. Ward. About 2 acres have been mined, and 20,000 tons were taken out. Mr. Ward states that operations were begun in 1895, and closed down in December, 1899, because the Standard Oil Company had sufficient earth on hand for the present. Bed No. 3 contains numerous poor fossils. Several species were collected, of which the following is a list.

List of fossils collected from fullers earth mine of Chesebrough Manufacturing Company, near Quincy, Florida:

Cypraea, agreeing in form and size with *C. pinguis* Conrad from the Chipola horizon.
Murex mississippiensis Conrad? *var.*
Fulgur spiniger Conrad?
Modulus sp.
Crucibulum auricula Gmelin.
Arca staminata Dall.
Pecten (*Nodipecten?*) sp.
Cardita serricosta Heilprin.
Chione sp.

These fossils indicate an upper Oligocene horizon, corresponding stratigraphically with No. 3 of Dall and Stanley-Brown's Rock Bluff section, which was given on a preceding page.

A specimen of *Carolia floridana* Dall, from the fullers earth horizon at Quincy, is in the United States National Museum. This is considered an index fossil of our upper Oligocene.

An examination of the section at the Owl Commercial Company's mine disclosed the following exposures :

Section of the Owl Commercial Company's mine.

4.	Overburden	5 to 20 feet.
3.	Fullers earth	6 to 10 feet.
2.	Sandstone containing crystal sand lumps of calcite or aragonite	3 to 4 feet.
1.	Fullers earth	5 to 6 feet.

The mining is done by stripping.

Fullers earth occurs along Quincy Creek above the Owl Commercial Company's works, about 1½ miles west of Quincy, on land belonging to Mr. William Bruce in Sec. 12, T. 2 N., R. 4 W. A specimen taken from an auger bore was donated by Mr. Bruce. The overburden along the creek flat is 4 or 5 feet thick. Mr. Bruce also donated some pieces of the material which came from a pit that is at present filled with water. A pit has also been dug in Sec. 2, T. 2 N., R. 4 W., on land belonging to Messrs. Taussig and Wedeles. Some pieces were picked up out of the dump around this hole. The overburden is from 4 to 5 feet thick, the same as on Mr. Bruce's land.

The fullers earth in these localities has not been thoroughly explored. It seems to be of good quality, the overburden is not great, and the land is flat. Transportation by railroad is within one-half to three-fourths of a mile. From what Mr. Bruce says, the deposit is thick enough for profitable working—about 8 feet.

LEON COUNTY.

Twelve miles west of Tallahassee, on property belonging to Messrs. W. H. Allen and Sons, are occurrences of fullers earth. Several pits have been sunk by Mr. Rosendale. The overburden is about 6 feet, and there are about 8 feet of fullers earth. The writer was not able to get fresh specimens, hence pieces from the dump were selected. The land lies rather flat, along a small creek running into the Ocklocknee River.

A section on the Seaboard Air Line Railway, about 1 mile east of Tallahassee, at milepost 163, shows the following exposures:

Section on Seaboard Air Line Railway.

3.	The upper 25 or 30 feet at the ends of the cut are reddish, yellowish sands.	
2.	Sands with clay partings	5 to 10 feet.
1.	Whitish or bluish clay resembling fullers earth in thin laminae with sand partings	4 to 5 feet.

In a curve in the railroad track between mileposts 163 and 164 is another cut between 15 and 20 feet deep, and the same section as above described was again seen. The clay at the base resembles more closely fullers earth than in the first described section. It contains less sand.

A fullers earth horizon is also mentioned in the Jackson's Bluff section, which is included under the discussion of the Miocene.

On the bank of the Ocklocknee River, one mile north of Holland postoffice, there is an exposure of hard light-gray limestone which was formerly quarried. The surface is now almost obscured by debris, but it is still possible to find small exposures which indicate that the beds are at least twelve feet thick. The upper four feet contains many specimens of *Carolia floridana* Dall, but the remainder of the outcrop is conglomeratic and appears to be almost destitute of fossils.

The following record of a well sunk by Mr. J. A. Henderson near the western limits of Tallahassee, was furnished by Vaughan:[1]

2.	Sands and clays	25 feet.
1.	Limestone containing clay layers	75 feet.

The limestone furnished *Ostrea rugifera* Dall, *Pecten chipolanus* Dall, *Anomia sp.*

On Rouse's Mill Creek, near West Sopchoppy, there is an exposure of about ten feet of soft light-gray sandstone. This rock is friable and resembles the Alum Bluff formation in texture. A few fossils occur in the sandstone, but they are too friable to obtain good specimens, only one identifiable specimen of *Pecten madisonius* var. *sayanus* Dall having been obtained.

At West Sopchoppy there is a bed of very fossiliferous marl which probably lies stratigraphically above the soft sandstone at the mill. The marl contains some material like that at the mill, but is much more calcareous and contains many shells. The thickness of the outcrop is about ten feet, but the base of the marl is not exposed, and hence its maximum thickness may be considerably greater. The marl furnished specimens of *Carolia floridana* Dall and *Scuttella sp.*

---

[1] Vaughan, T. Wayland. Unpublished notes.

In addition to the localities given above, the Alum Bluff formation is exposed at other localities, some of which will be enumerated in the succeeding paragraphs.

An exposure at White Springs on the Suwanee River is referred to the Alum Bluff formation. The section given below was measured with a hand level at the point where the wagon bridge spans the river.

1.	Dark colored sandy loam	1 foot.
2.	Dark colored semi-indurated sand	5 feet.
3.	Unconformity	
4.	Greenish thinly-laminated siliceous clay	8 feet.
5.	Light yellow sand containing many casts of shells	17 feet.
6.	Fine grained light gray sand	11 feet.
7.	Light gray arenaceous and calcareous sandy marl	51 feet.
8.	Light gray arenaceous marl with nodules of chert	12 feet.
9.	Alternating beds of bluish sand and light green sticky marl containing thin layers of limestone, nodules of chert and some imperfect oyster shells	2 feet.
10.	Gray sand with thin nodular and brecciated layers of limestone	3 feet.
11.	Alternating beds of sand and light gray shell marl containing many well preserved fossils near the base of the section	6 feet.

River level reported four feet above low water stage.

Nos. 1 and 2 of the foregoing section are the ordinary Quaternary sand which covers a large part of the State.

Nos. 4 to 11 inclusive probably belong to the Alum Bluff formation.

From the material collected near the base of No. 11, Dr. Vaughan identified the following fossils:

Locality:—White Springs, Florida, at water level, wagon bridge.
  Ostrea rugifera Dall.
  Pododesma scopelus Dall.
  Pecten madisonius var. *sayanus* Dall.
Geologic horizon:—Apalachicola group, Alum Bluff formation.

On the Ocklocknee River, about one-quarter mile above Stuart Bridge, there is an exposure of thinly laminated light-gray to white marl. The outcrop has a thickness of about six feet, and the material is so brittle that it was difficult to secure fossils.

Rocky Bluff on the Manatee River, about one mile from Ellenton, was visited by Heilprin,[1] who says:

> The "Bluff" we found to be a ledge of rock, rising about two or three feet above water-level at the time of our visit, and consisting of at least two well-defined layers—a basal white "marl" and yellowish sandstone, and an overlying siliceous conglomerate. The latter is almost entirely deficient in organic re-

---

[1] Heilprin, Prof. Angelo. Wag. Free Inst. of Science, vol. i, 1887, p. 13.

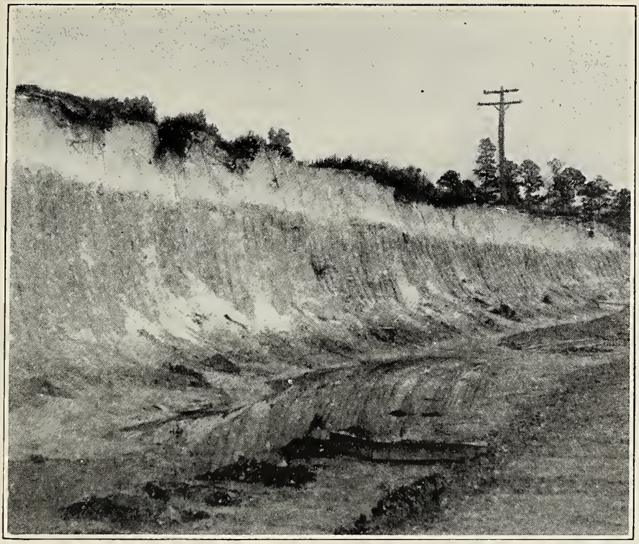


Photo by L. W. Stephenson.

FIG. 1.—CUT ON G. S. AND F. R. R. NEAR KENT, NASSAU COUNTY, FLA., SHOWING FINE VARI-COLORED ARGILLACEOUS SAND (AGE UNCERTAIN) OVERLAIN BY LOOSE, GRAY PLEISTOCENE SAND.

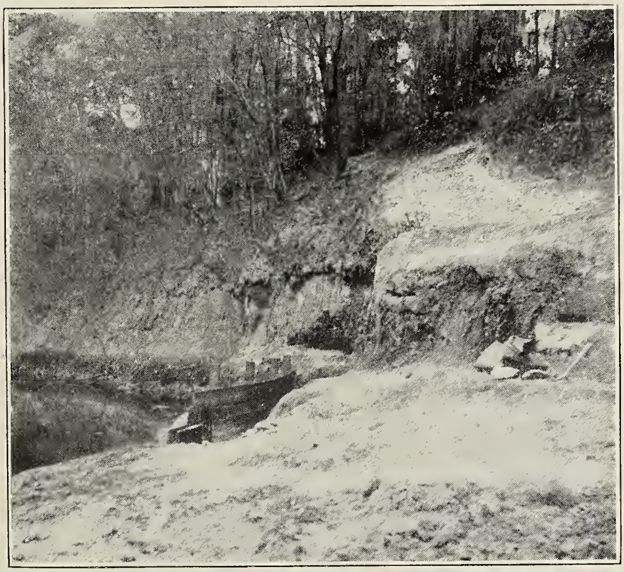


Photo by L. W. Stephenson.

FIG. 2.—ALUM BLUFF FORMATION NEAR WHITE SPRINGS. TAKEN A SHORT DISTANCE ABOVE ROCK ISLAND AT LARGE SPRING, ON SUWANEE RIVER.

mains, whereas the marl is densely charged with them. Among the recognizable forms occurring here, I determined a number of well-known and distinctive Miocene species of mollusks, such as *Pecten Jeffersonius, P. Madisonius, Perna maxillata, Venus alveata, Arca incongrua,* etc., which left no doubt as to the age of the deposits in which they were imbedded.

The exposures in the vicinity of Ellenton are of considerable interest because they contain valuable deposits of fullers earth.

Three-fourths of a mile southeast of Ellenton, a section was measured, which showed:

1.	Dark gray to black sandy loam	4 to 6 feet.
2.	Dark colored clayey sand, containing chert pebbles, worn and rounded fragments of bones, and sharks' teeth. "Clam" shells are said to occur in this bed, but none could be found	0 to 2 feet.
3.	Unconformity.	
4.	Dense thinly laminated light gray fullers earth, weathering pale yellow	5 to 8 feet.
	Total	9 to 16 feet.

About one-fourth of a mile farther east is another exposure which shows both the fullers earth and the underlying limestone. Here the sandy loam and fullers earth are both thinner than at the other locality.

1.	Light and dark gray sandy loam, about	1 foot.
2.	Black clayey loam with bone fragments	1 foot.
3.	Unconformity.	
4.	Light gray fullers earth	2-3 feet.
5.	Dense light gray to pale yellow impure fossiliferous limestone (above water)	4 feet.
	(below water)	9+ feet.
	Total	17+ feet.

This is the locality which is known as Rocky Bluff. The material which Heilprin[1] called sandstone appears to be a coarse-grained sandy limestone. Shells and fragments of bone are numerous in certain horizons; but the rock is so brittle that it is difficult to get good collections. The presence of *Turritella alcida* Dall, and *Pecten madisonius* var, *sayanus* Dall have led to this limestone being referred to the Alum Bluff formation, but larger collections may show that it belongs to some other subdivision of the Apalachicola group. The exact relation of the fullers earth bed to the limestone was difficult to determine, though it is apparently conformable; and if so, it belongs to the Oligocene. Heilprin's reference of the exposures at Rocky Bluff to the Miocene appears to have been an error, unless he intended to use the term Miocene in the sense in which it was formerly employed, to include the Apalachicola group of the Oligocene.

---

[1] Loc. cit.

Chipola Marl Member:—The Chipola marl member forms the basal portion of the Alum Bluff formation and rests conformably upon either the Chattahoochee or the Hawthorne formation. At the type locality of the Alum Bluff formation it constitutes the basal division of that formation, but farther north it thins and permits the sandy beds of the Alum Bluff to lap over on the Chattahoochee formation. This overlap is probably explained by the gradual shoaling of the water which prevented the development of abundant organic life toward the north. As the sands were deposited farther south, they gradually encroached upon the area where marl had previously been forming. According to this hypothesis, there would be no necessity for an erosion interval between the Chattahoochee and the Alum Bluff formations for a gradual emergence of the land or a filling of the shallow water along the margin of the sea would permit the deposition of sands upon the limestones and marls.

When fresh, the Chipola marl member consists of a light gray to yellow marl, containing many shells and shell fragments. The matrix is composed of calcareous clay containing a small percentage of fine sand. When weathered, the marl becomes dark yellow or reddish-yellow from the presence of hydrated iron oxide. The character of the deposit indicates comparatively quiet water with conditions especially favorable for the development of organic life. In some localities this horizon is represented by a very sandy marl. The "Sopchoppy limestone," which Dall has assigned to the Chipola marl horizon, varies from a soft white or light gray to a dense gray limestone, which is occasionally cherty. Some beds of soft sandstone are doubtfully referred to this horizon. The beds contain layers which appear to have been broken and recemented, thus forming a brecciated limestone which is said to be somewhat phosphatic. Locally the rock is abundantly fossiliferous, containing imprints of shells and fragments of bones.

The Chipola marl member of the Alum Bluff formation is not known to have a thickness of more than fifteen feet and the average is probably only a few feet. The limestone belonging to this member is so imperfectly known that it is difficult to make a satisfactory estimate of its thickness. The maximum exposure, which has been reported, is about ten feet.

The fauna of this member has been studied by Dall,[1] who says: "The fauna comprises three hundred and thirty-three species, to which we may expect additions on further exploration. A species of *Or-*

---

[1] Dall, Wm. H., Wag. Free Inst. Trans., vol. iii, pt. 6, 1903, pp. 1574-1575.

thaulax different from that found in St. Domingo or the Tampa "*Orthaulax* bed," a rich development of the genus *Marginella,* a species of the group of *Oliva* called by von Martens *Omogymna,* a species of *Spheniopsis,* heretofore only known from the European Oligocene, these are among the interesting features of the fauna."

According to Dall[1] the "Sopchoppy limestone" contains orbitolites and "about thirty species of shells, most of which are common to the Chipola marl or the *Orthaulax* beds." Judging from the presence of fragments of bones occurring in this limestone at some localities, a vertebrate fauna of considerable size is doubtless represented, but no attempt has been made to procure collections, and hence its characteristics are unknown.

"This group of species is distinctly subtropical, but less indicative of warm seas than the Bowden marl of Jamaica, with which the Chipola beds have sixteen species in common. Only one species is known to be found both in the Chipola beds and the Oligocene of St. Domingo. About half the species in the Chipola marl are peculiar to it, and of the others the largest percentage is found in the Tampa silex beds, while in the subsequent Oak Grove sands twenty-four per cent. of the Chipola species occur. Thirty-five species survive to the existing fauna."

The type locality of the Chipola marl member is the McClelland farm, which is situated on the west side of the Chipola River just south of Ten-Mile Creek. Here the marl was formerly mined, but at the present time the pit is covered with sand and debris, so that the deposit can only be reached by digging. The section given by Dall[2] is:

Superficial sands, 1 to 3 feet, say..	2 feet.
Chipola marl, varying from	7-12 feet.
Chattahoochee limestone at water's edge, extending below not less than	6 feet.
Total thickness	20 feet.

The marl is exposed on the north bank of Ten-Mile Creek, where it attains a thickness of six to twelve feet, and is underlain by the Chattahoochee formation which is exposed at a natural bridge two or three hundred yards farther down stream. At this locality the marl has the same general characteristics as in McClelland's marl pit. Other small exposures are reported on the Chipola River near the McClelland farm, and at the base of Alum Bluff.

---

[1] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey Bull. No. 84, 1892, p. 120.

[2] Dall, Wm. H., Geol. Soc. Am. Bull., vol. v, 1893, p. 159.

Oak Grove Sand Member:—On paleontologic grounds, Dall[1] has correlated the Oak Grove sand member with the typical sands of the Alum Bluff formation. The correlation[2] has been made because of the presence in both of *Ostrea trigonalis, Pecten sayanus,* a *Pododesmus* and *Turritella alcida* Dall.

The Oak Grove sand member consists of fine-grained, light gray to greenish sands containing many excellently preserved shells. It is a sandy shell marl, which often has a considerable admixture of calcareous material. The Oak Grove sand member is not fully exposed at the type locality and it may attain a thickness of several feet, but the observed thickness is only a few feet.

The fauna of the Oak Grove sand member is closely related to that of the Chipola marl member, but it contains large species of both *Cardium* and *Lyropecten,* which appear to foreshadow the large species of those genera occurring in the Miocene marls.

Owing to the heavy rains, the Oak Grove sand member was submerged at the time that locality was visited. The exposure is said to be less than four feet in thickness and to consist of light gray, extremely fossiliferous sand. The Oak Grove sand member was subsequently examined by Vaughan[3] who reports the following section:

Section of bluff, Yellow River, about 100 *yards below road bridge.*

Fine yellow sands	9 feet.
Very fossiliferous gray sandy marl extending below level of water in the river at least 1 foot..	2 feet.
Total	11 feet.

Dr. Vaughan examined an exposure of marl on the south side of the river at Crowders Crossing in Section 5 T., 3 N., R. 21 W. At this locality, a blue or bluish-green marl rises about two feet above the river at a very low stage of water. This exposure is probably the stratigraphic equivalent of the Oak Grove sand member.

Shoal River Marl Member:—The Shoal River marl member, which has recently been recognized by Vaughan,[4] lies stratigraphically about thirty feet above the Oak Grove sand member. It thus forms the upper part of the Alum Bluff formation. In the following section at Shell Bluff, the lower sand represents the Oak Grove sand member and the upper fossiliferous marl horizon is the Shoal River marl member.

---

[1] Dall, Wm. H., Cenozoic Geology along the Apalachicola River, Bull Geol. Soc. Am., pp. 166-167, and p. 170.

[2] Dall, Wm. H., Tertiary Faunas of Florida, Wagner Free Inst. of Sci. Trans., vol. 3, pt. 6, 1903, p. 1588.

[3] Vaughan, T. Wayland. Unpublished notes.

[4] Vaughan, T. Wayland. Unpublished notes.

Section at Shell Bluff, (*S.* 4, *T.* 3, *N.*, *R.* 21 *W*).

8.	Gravel covered slope, gravel elipsoidal, ½ inch probably usual length, rarely 1 inch, mostly quartz, in rather coarse red sands	30 feet.
7.	Gray, finer sand, blotched yellow, decidedly argillaceous, est.	10 feet.
6.	Greenish shell marl, matrix arenaceous, fine fossiliferous (Shoal River marl member)	27 inches.
5.	Non-fossiliferous, coarser greenish sands, becoming argillaceous at base	3 feet.
4.	Green clay	6 inches.
3.	Coarser sands, gray, greenish, last 2½ feet, loose, purple and white sands	6 feet.
2.	Unexposed	15 feet.
1.	Non-fossiliferous green sands, oxidized yellowish on surface (Oak Grove sand member)	10 feet.
	Total of section, about	80 feet.

Lithologically this member consists of interbedded, greenish sands, clays and marls. The color is usually greenish, oxidizing yellow, occasionally whitish or purplish, and the material varies in texture from fine clay to sand.

The Shoal River marl member of the Alum Bluff formation is about fifty feet thick. Some idea of its observed thickness may be gained from a study of the sections of the marl. This member of the Alum Bluff formation is very fossiliferous, and extensive collections were made by Dr. Vaughan, but they have not yet been studied in sufficient detail to permit the formulation of a comprehensive statement concerning the fauna.

Dr. Vaughan[1] also examined the exposure at Senterfitt Creek.

> The fossiliferous marl forms a platform 20 to 30 feet wide along the base of the bluff, sloping (at the present stage of the water) from 2 feet next the bluff to 1 foot along the river edge above the water. The surface in places is practically covered with shells freed from the matrix. The weathered marl is an ashy gray, but when fresh, dark bluish.
>
> After studying this exposure and collecting from it I revisited the exposure at Senterfitt Grist Mill, from which I collected in May, 1903. The latter locality is by aneroid 30 feet above the fossil bed at the Oak Grove bridge; and is 2 miles northeast of that locality. The marl bed on Senterfitt Creek is, therefore, stratigraphically slightly above the Oak Grove horizon.
>
> The Senterfitt horizon seems very persistent, extending at least from the Yellow River to Argyle.

Other localities mentioned by Vaughan[2] are: On the north side of the river, at the head of the first draw below Shell Bluff, about 400 yards northwest of the bluff, and 200 yards from the river; along the south side of Adam's Mill Creek, near the top of a low bluff, and on Hulion Mill Creek, Sec. 7, T. 3, N., R. 21 W.

---

[1] Vaughan, T. Wayland. Unpublished notes.

[2] Vaughan, T. Wayland. Unpublished notes.

In addition to the localities previously mentioned, there are exposures of the Shoal River marl member at various localities in Walton County. This member outcrops in the valleys on the west side of the Choctawhatchee River in the vicinity of Knoxhill, and westward in the vicinity of Eucheanna. It is also reported southwest of DeFuniak Springs. A well on the farm of Mr. Neil Campbell near Knoxhill penetrated the following beds:

Yellow sandy clay	16 feet.
Blue shell marl (Shoal River)	12 feet.
White micaceous sand with many shell and some sharks' teeth (Oak Grove?)	8 feet.
Total	36 feet.

Fossils obtained at a depth of thirty-three feet from Mr. Dave George's well, nine miles southeast of De Funiak Springs, seem to show the presence of the marls belonging to the Shoal River member; and what is probably the same marl is exposed on Folks Creek one and a half miles southwest of Dave George's house. The Shoal River marl member was discovered in digging a mill race, about one mile east of Argyle. At this locality, the following section was measured:[1]

Yellow sand and gravel	2 or 3 feet.
Yellow sand and clay	2 feet.
Blue fossiliferous marl	3 feet.

MIOCENE.

General Remarks:—The first account of Miocene rocks in Florida was published in 1881, when Dr. Smith[2] made known the results of his investigations carried on in connection with the statistical work for the Tenth Census of the United States. Dr. Smith's original Miocene locality is at Rock Spring in Orange County, where he collected a series of fossils from an exposure of soft limestone. These fossils were identified by Heilprin as Miocene. Dr. Smith did not make any attempt to correlate the Miocene at Rock Springs with that at any other locality nor did he give the beds a local name.

As already noted in the discussion of the Oligocene, the term Miocene was used for some time to designate all the rocks in this region belonging stratigraphically between the Vicksburg group (then called Eocene) and the known Pliocene and Quaternary. During that period the Apalachicola group (Upper Oligocene) was known as the "Old or Sub-tropical Miocene," and the true Miocene was discriminated by the use of such terms as "newer," "cold water," or "Chesapeake" Miocene. As early as 1897[1] paleontologic studies determined the proper correlation for the rocks of Oligocene age, and thus left in the Miocene that portion which was formerly known as "new" or "Chesapeake" Miocene. This usage is in accordance with the later papers of Dall.[2]

---

[1] Vaughan, T. Wayland. Unpublished notes.

[2] Smith, E. A., On the Geology of Florida. Amer. Jour. Sci., 3rd ser., vol. xxi, pp. 302-303.

To the beds of true Miocene age Dall[3] gave the name "Chesapeake group." This name was originally proposed by Darton[4] for the Neocene beds of Maryland and Virginia bordering on Chesapeake Bay and belonging to Dana's Yorktown epoch. Chesapeake as used by Darton is the name of a formation, but it was subsequently used by Dall to include a number of beds which he designated the Chesapeake group. "The term *Chesapeake group*, as independently suggested, here includes as typical Darton's Chesapeake formation and also all other beds belonging to the same horizon and containing the same general fauna on the Atlantic and Gulf coasts of the United States."[5] In accordance with the usage proposed by Dall, the name Chesapeake is a general term to include all of the Miocene of the Coastal Plain.

In 1892, Dall[6] divided the "Chesapeake" of Florida into two formations, which he called Jacksonville limestone and *Ecphora* bed. In a subsequent paper by the same author these two divisions are placed together. "After the elimination of the Oligocene series from the so-called Miocene of Florida, we have remaining practically only one series of beds, which have been identified over a considerable area of northern Florida. The Miocene appears as a soft limestone rock in the vicinity of Jacksonville, and has been traced by material from artesian wells on the east side of the peninsula as far south as Lake Worth. The layers of fossiliferous marl in the vicinity of the Chipola River, at Alum Bluff, and other localities in Western Florida are usually less than thirty feet in thickness, but counting unfossiliferous clays, etc., it has been estimated that the rocks of this age in Florida may have attained to a thickness of some five hundred feet or less."[7]

---

[1] Dall, Wm. H., Descriptions of Tertiary fossils from the Antillean region. U. S. Nat. Mus. Proc., vol. xix, No. 1110, 1896, p. 303.

[2] Eighteenth Ann. Rept., U. S. Geol. Survey, p. 329, 1896-97. The Floridian Miocene, Trans. Wagner Free Inst., 1886-1903, p. 1594.

[3] Dall, Wm. H., and Harris, G. D. Neocene of North America. U. S. Geol. Survey, Bull. 84, 1892, p. 122.

[4] Darton, N. H., Mesozoic and Cenozoic formation of eastern Maryland and Virginia. Geol. Soc. Amer. Bull. 2, pp. 443-445.

[5] Dall, Wm. H., Neocene of North America. U. S. Geol. Survey, Bull. 84, 1892, p. 123.

[6] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, p. 124.

[7] Dall, Wm. H., The Tertiary Faunas of Florida, Wagner Free Inst., Trans., vol. iii, part 6, 1893, p. 1594.

In Florida the limestones, clays and sandstones of the Miocene are lithologically so unlike the shell marls that in the absence of satisfactory paleontologic evidence for their exact correlation it seems best to describe them separately. The two divisions are, therefore, retained, but a new name is given to the marl. The "*Ecphora* bed" of Dall is here called the Choctawhatchee marl, from the river in western Florida where it is well exposed. At Dall's type locality the Jacksonville formation is known only from well records and excavations; hence, the name is not entirely satisfactory. However, the Committee on Geologic Names of the U. S. Geological Survey has decided to retain Jacksonville as the name of the formation because (1) it is reasonably well fixed in the literature, and (2) the type fauna was collected at Jacksonville. The existence of exposures on Black Creek, in Clay County, however, would have led to the adoption of another name if Jacksonville had not already been used. The samples of rock from wells on the east coast indicate that the limestone beds are thin and form only a minor part of the Miocene in that portion of the State; hence the word *formation* is here substituted for *limestone*.

JACKSONVILLE FORMATION.

The Jacksonville formation was first recognized by Dall, who obtained samples of the rock, together with fossils showing its age, from an excavation at the Jacksonville Water Works.[1]

Stratigraphic Position:—The Miocene beds lie stratigraphically between the underlying Oligocene and the overlying Pliocene and Pleistocene formations. From well records and samples obtained along the east coast of Florida, the Jacksonville formation appears to rest unconformably upon the eroded surface of the limestones of the Vicksburg group at Jacksonville, St. Augustine, and other localities. Farther westward, it probably rests on the beds belonging to the Apalachicola group, but no contacts were observed.

Lithologic Character:—When fresh, the limestone of the Jacksonville formation varies in color from light gray to nearly white, but upon weathering it changes to pale yellow or yellowish gray. It usually has a porous texture, but occasionally becomes hard and dense. The presence of a large percentage of clear quartz sand may be easily distinguished by the use of an ordinary hand lens, and microscopic examination shows there is also a large amount of clayey material which varies in color from light gray to pale yellow. In certain horizons fossils are very abundant, the shells having usually been dissolved, leaving nothing but casts or molds; and this fact, together with the friable character of the rock, makes it very difficult to obtain satisfactory collections. However, enough material has been obtained to indicate the Miocene age of the rock. Unlike the Choctawhatchee marl, the Jacksonville formation appears to contain practically no mica. It also differs from the marl in its relatively higher percentage of lime, and a correspondingly lower percentage of sand.

---

[1] Dall, W. N., U. S. Geol. Surv., Bull. 84, pp. 124-125.

Although the Jacksonville formation is fossiliferous, the organic remains are less numerous and in a much poorer state of preservation than in the Choctawhatchee marl. An examination of well samples shows that limestone forms only a minor part of the formation, a fact which is well illustrated by the log of the well at Jacksonville, where the formation attains a thickness of about 500 feet and is composed largely of arenaceous and siliceous beds. From samples obtained in drilling a well at Jacksonville the clays are known to be siliceous and the hard materials described as gravel found to be chert nodules. Some of the beds consist of a hard, gray, siliceous rock which appears to have been formed by the replacement of the calcareous portion of a sandy limestone by silica which was probably derived from organic remains such as sponge spicules and diatoms. A detailed log of the Jacksonville well, supplied by Supt. R. N. Ellis, is given below:

	Feet.
Filled ground and sand	0 - 15
Varicolored gray to red sand	15 - 34
Gravel	34 - 34½
Yellowish fossiliferous rock	35 - 40
Gravel with water	40 - 44
Gray fossiliferous rock	44 - 53
Clay with thin layers of white rock	53 - 58
Blue clay with black gravel at 58-70 and 82-89 feet	58 - 89
Rock	89 - 94
Blue clay with black gravel	94 -100
Rock, 2 inches thick	100
Blue clay with quartz sand and very fine black gravel	100 -130
Very hard compact clay and sand	130 -142
Greenish sandy clay	142 -204
Greenish sandy clay with more or less black gravel and occasional streaks of pure clay	204 -250
Sticky clay with sand and fine gravel	250 -263
Rock	263 -263½
Greenish sandy clay with heavy gravel bed	263½-272
Blue clay containing very fine sand	272 -287
Sand rock	287 -289
Bed of shells, oysters, etc., living types	289 -290
White clay	290 -294
Sand with clay enough to hold it	294 -298
Compact greenish sandy clay with streaks of nearly pure clay	298 -314
Sand containing shells with just enough clay to hold them	314 -320
Shells with scraps of fossil bone	320 -330

"Coquina" rock	330 -331
Clay	331 -340
Blue clay and sand	340 -350
Sticky blue clay; very little sand	350 -358
Clay with black gravel	358 -365
Blue clay with gravel and shell casts	365 -368
White clay with gravel	368 -375
White marl with very little sand	375 -385
Light-colored clay	385 -390
Greenish clay	390 -400
Greenish sandy clay	400 -410
Sticky clay	410 -428
Clay with very little sand	428 -434
Nearly pure clay; very light when dry	434 -443
Bluish sandy clay with gravel and streaks of sticky clay with some nodules of rock	443 -470
Rock	470 -470½
Greenish clay with fine sand above and coarse sand below; small flow of water at 487 feet	470½-487
Rock boulder (siliceous concretion) in blue sandy clay	487 -492
White clay	496 -497
Compact blue clay	492 -496
Conglomerate rock	497 -499
Hard brownish rock	499 -504
Very hard compact rock (siliceous limestone)	504 -510
Soft white rock with some water	510 -519
Hard compact rock	519 -524
Very soft white rock in layers 1 to 5 feet thick with strata of more compact rock 3 to 12 inches thick; increase in the flow of water on breaking each hard stratum. Gaged flow at 632 feet 1,000,000 gallons in twenty-four hours	524 -727
Compact brown rock; no water	524 -727
Alternate hard and soft strata of grayish rock with very little water	758 -865
Soft white rock with hard brown layers 1 to 3 feet thick every few feet; a slight increase of flow from each soft layer	865 -930
Very hard brown rock	930 -935
Soft brownish rock with hard layers, flow increasing as each hard layer is broken	935 -950
Alternate layers of hard and soft rock; small increase in flow	950 -970
More compact rock; no water	970 -980

The sands and gravels from 0-34 1-3 feet are probably Pleistocene though they may include some Pliocene beds.

The fossiliferous limestone encountered at thirty-five feet is the Jacksonville. The rocks belonging to this formation continue to a depth of at least 496 feet.

Thickness:—The exposures of the limestone of the Jacksonville formation seldom exceed five or six feet in thickness, but there is a maximum exposure of about fifteen feet at a locality two miles above Middleburg on Black Creek.

Concerning the thickness of the Miocene in Florida, Dall[1] says:

> The Chesapeake group is represented over a very wide area in Florida, if the scattered observations already made can be regarded as indicative of its extension. Borings on the eastern coast of Florida and in the St. Johns valley indicate that there the beds of this group in some places attain a thickness of at least 500 feet.
>
> Some uncertainty arises when thickness is estimated from samples of rock obtained from borings, and the difficulty is increased several fold when it is necessary to rely upon descriptions prepared by drillers.

The information relating to the thickness of the Jacksonville formation at various points on the east coast will be discussed in connection with the detailed sections; and it is only necessary here to note that Dall's estimate of the thickness of the formation is probably essentially correct. Samples obtained from a well at Jacksonville indicate that at that locality the formation has a thickness of over 460 feet. This is shown by the fact that the limestone phase of this formation was encountered at a depth of thirty-five feet; and there was obtained at a depth of 495 feet a shark's tooth which does not occur in rocks older than the Miocene.

Physiographic Expression: — Where the Jacksonville formation lies near the surface characteristic sink-hole topography is sometimes seen. This is the case at the original Miocene locality near Rock Spring; but here, as in some other localities, it is impossible to say how much of the topography is due to the underlying porous limestone of Oligocene age.

Paleontologic Characters:—Owing to the difficulty of obtaining good collections, the fauna of the Jacksonville formation is imperfectly known. Dall[2] reports fossils from various localities, among them being *Pecten jeffersonius, Carditamera arata,* etc., from Preston sink three miles north of Waldo; and *Venus rileyi, V. permagna* and *Arca limula* in a well at St. Augustine at a depth of 208 feet.

Heilprin[3] identified *Pecten madisonius, Venus alveata, Venericardia granulata, Carditamera arata, Mytiloconcha incurva, Cardium sublineatum* and *Oliva literata* from Rock Springs, Orange County.

During the progress of the recent field work a few fossils were obtained from exposures on Black Creek. While the collections were small, it was possible for Dr. Vaughan to determine a few species. The lists of these are given on subsequent pages.

Structure:—The Jacksonville formation presents no peculiarities of structure, and appears to have undergone no considerable disturbance since its deposition. The exposures are found bordering those of the rocks belonging to the Apalachicola group and there is a gentle dip seaward. The Miocene beds were probably affected by the general arching of the strata of the State, though presumably the initial movement took place before their deposition.

---

[1] Dall, Wm. H. Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, p. 124.

[2] Dall, Wm. H. Neocene of North America, U. S. Geol. Survey Bull. 84, 1892, pp. 124-125.

[3] Smith, E. A., Am. Jour. Sci., 3rd ser., vol. xxi, 1881, p. 302.

Local Details:—On Black Creek the Jacksonville formation is exposed at intervals for a distance of several miles, but the thickness of single exposures seldom exceed six feet. On the north bank of Black Creek, about five miles above the Atlantic Coast Line Railroad, there is a section showing five feet of the limestone overlain by six to eight feet of light gray sand and sandy loam. At this locality, the rock consists of massive beds of the typical light gray porous limestone containing a considerable admixture of sand and clay. The weathered surface varies in color from pale yellow to buff, and owing to the solution and removal of the lime, the weathered rock often appears to be a calcareous sandstone. Exposures of the limestone occur at intervals for a distance of about two miles above this locality; and then give place to Pleistocene and alluvial sands. Fossils are abundant in the form of casts and moulds which are often very beautifully preserved, but are difficult to procure because of the friable character of the matrix. The following fossils[1] were collected at this locality:

Locality:—Five miles west of railroad bridge, Black Creek, Fla.

Pecten madisonius Say. (Scales on ribs fine, suggesting *var. sayanus* Dall.)
Carditamera cf. *arata* Conrad.
Cardium, probably *robustum* Solander.
Venus rileyi Conrad.

About two miles above Middleburg, on the north bank of the creek, the Jacksonville formation again appears in a bluff about twenty-five feet high.

Section about 2 miles above Middleburg on north bank of Black Creek.

Light gray sandy loam	6-8 inches.
White Pleistocene sand	2 feet.
Erosion unconformity	
Red sandy clay	4 feet.
Erosion unconformity	
Dark blue to brown sandy clay plastic when wet, granular when dry	4 feet.
Unconformity	
Soft porous light gray, siliceous and arenaceous limestone, very fossiliferous with casts chiefly of bivalve shells	10 feet.
Soft dense light gray limestone similar to above to water	4 feet.

The Miocene age of the limestone is shown by the following list of fossils,[2] collected from the upper part of the beds:

---

[1] Identifications by T. Wayland Vaughan.

[2] Identifications by T. Wayland Vaughan.

Locality: — Two miles above Middleburg, north side of Black Creek.

Glycymeris subovatus Say.	*Carditamera* cf. *arata* Conrad.
Arca staminea Say.	*Cardium robustum* Solander.
Arca cf. *subrostrata* Conrad.	*Venus* cf. *rileyi* Conrad.

The Jacksonville formation is exposed at several points along the creek above this locality, but the thickness of the outcrops seldom exceeds three or four feet.

Excavations[1] at the city water works at Jacksonville revealed the presence of a yellowish siliceous limestone containing casts and molds of fossils. The specimens obtained from this locality included *Pecten jeffersonius* and *Carditamera.*

According to Dall,[2] some of the rock at Live Oak and Lake City may also belong to the Miocene, but as yet this opinion lacks confirmation.

The log of a well drilled at the Jacksonville Water Works under the direction of R. N. Ellis, superintendent, indicates that the Jacksonville formation was encountered at a depth of thirty-five feet. An incomplete set of samples from another well at this locality makes it possible to fix the top of the Vicksburg group at a depth of about 524 feet from the surface. This leaves a thickness of 489 feet which, judging from the description of the well log, appears to be composed of sand, clay, shells, etc., to be assigned to the Miocene and the Apalachicola group of the Oligocene. From the presence of a shark's tooth belonging to a post-Oligocene species in a sample obtained at a depth of 495 feet, it would seem that the Miocene extends to that depth, and the Apalachicola group, if present is thus restricted to about thirty feet of alternating beds of hard and soft silicified rock. Lithologically, this material bears a much closer resemblance to the overlying Miocene beds than it does to the Oligocene, and this has led to the inference that the Miocene may here rest directly upon the Vicksburg group.

In the well at the Ponce de Leon Hotel, St. Augustine, about thirty-seven miles southeast of Jacksonville, the Miocene appears to have been encountered at a depth of 110 feet. According to Dall,[3] the Miocene fossils *Venus rileyi, V. permagna* and *Arca limula* were encountered at a depth of 208 feet, while fossils characteristic of the Vicksburg group were obtained at 224 feet. This would indicate that the Miocene which here has a thickness of 114 feet may rest directly upon the Vicksburg group.

---

[1] Dall, Wm. H. Neocene of North America. U. S. Geol. Survey, Bull. 84, 1892, p. 124.

[2] Ibid, p. 125.

[3] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, p. 125.

At Rock Springs, the original Miocene exposure, the rock consists of a light gray to white marly limestone containing a number of characteristic fossils. At this locality, Smith[1] collected *Pecten madisonius, Venus alveata, Venericardia granulata, Carditamera arata, Mytiloconcha incurva, Cardium sublineatum?* and *Oliva literata?* According to Dall, Miocene fossils were also obtained in a boring at Lake Worth on the east coast.

CHOCTAWHATCHEE MARL.

The Choctawhatchee marl includes the "*Ecphora* bed"[2] and "aluminous clay"[3] of Dall. It comprises a grayish sandy shell marl and gray plastic sandy clay of Miocene age. It lies stratigraphically between the Oligocene and Pliocene beds, and contains characteristic species of Miocene fossils.

Stratigraphic Position:—The Choctawhatchee marl rests unconformably upon the Alum Bluff formation at Alum Bluff,[4] where the contact shows a wavy surface marked by shallow channels due to erosion. At this locality there is also a sharp change from the coarse light gray sands of the Alum Bluff formation, which contain few fossils, to the bluish-gray shell marl of the Choctawhatchee, with its abundant fauna. Several years ago Dr. Vaughan noted similar evidence of an unconformity between the Oligocene and Miocene at Jackson's Bluff on the Ocklocknee River. This fact is well shown by his section[5] at that locality:

Section at Jackson's Bluff, Ocklocknee River.	*Thickness.*	
	Feet.	*Inches.*
10. Sandy soil, thickness not determined........................		
9. Unexposed in slope to top of bluff face, about...............	16	
8. Yellow sands unconformably overlying the Choctawhatchee marl	5	
7. Yellow sandy fossiliferous Choctawhatchee marl, in places where unweathered of a greenish color	6	6
(There are about 3 feet additional under the yellow sands. This bed is extremely fossiliferous and from it I obtained the species listed by Dr. Dall in his discussion of the Florida Miocene.)		

---

[1] Smith, E. A., Am. Jour. Sci., 3rd ser., 1881, vol. xxi, p. 302.

[2] Dall, Wm. H., Neocene of North America U. S. Geol. Survey, Bull. 84, 1902, p. 124.

[3] Dall, Wm. H., and Stanley-Brown, Joseph, Cenezoic Geology Along the Apalachicola River, Geol. Soc. Am., Bull. V, 1894, pp. 168-169.

[4] Vaughan, T. Wayland. Unpublished notes.

[5] Vaughan, T. Wayland. Unpublished notes.

Section at Jackson's Bluff, Ocklocknee River. (Continued.)	*Thickness.* *Feet.*	*Inches.*
6. Yellow calcareous clay, same horizon Williams fullers earth.. The upper surface of this stratum is extremely irregular. There are small channels in it, one is about 5 feet wide and more than a foot deep. The basal 6-10 inches of the overlying bed are very largely composed of small pebbles and in it are imbedded pieces and fragments of the calcareous clay. There were apparently cracks in the calcareous clay and small pebbles went down into them. The contact is distinctly one of erosion unconformity.	5	6
5. Stiff bluish clay	6	
4. Calcareous sand	6	
3. Limestone ledge	2	
2. Greenish sands passing beneath the level of the water in the river	7	
Total	54	

This section is located in the S. W. ¼, Sec. 16, T. 1S., R. 4 W., in a southwesterly bend of the Ocklocknee River.

The paleontologic evidence indicates a stratigraphic break between the Oligocene and Miocene as is shown by the following quotation:

> As I have on various occasions insisted, the faunal gap between the uppermost Oligocene (Oak Grove) and the Chesapeake (Choctawhatchee) or Miocene is the most sudden, emphatic, and distinct in the whole post-Cretaceous history of our southeastern Tertiary, and indicates physical changes in the surrounding region, if not in Florida itself, sufficient to alter the course of ocean currents and wholly change the temperature of the waters on our southern coast. (Wagner Free Inst. Trans., p. 1594.)

The relation between the Miocene and Pliocene beds of Florida will be discussed later.

Lithologic Character:—Lithologically the two members of the Miocene in Florida are very unlike, both in character of the material and state of aggregation. The Choctawatchee marl varies from greenish gray to light gray in color, and consists of quartz sand containing very large admixtures of shells and shell fragments, and a smaller percentage of calcareous sand. In some parts of the formation the shells comprise a large percentage of the whole, and they are often in an excellent state of preservation. Elsewhere the organic remains form a very subordinate part of the whole or they may be entirely wanting. One phase of this formation is distinctly plastic, and was called "aluminous clay" by Dall and Stanley-Brown.[1]

When examined with a microscope, the marl is found to consist of clear quartz sand, of medium fineness, coated and partially cemented with calcium carbonate mixed with more or less dark colored clay. The presence of calcium carbonate may be detected by the effervescence when treated with dilute hydrochloric acid. There is also a certain amount of dark colored clayey material which appears in the form of a flocculent sediment in water. This material varies from light gray to nearly black, and is without doubt organic matter. In addition, hydrous iron oxide may be detected, usually in the form of a coating about the sand grains, or as a stain along the cracks and on the exposed surfaces of the beds. It is this iron compound which sometimes gives the exposed surfaces a rusty color.

---

[1] Dall, Wm. H., and Stanley-Brown, Joseph. Cenozoic Geology along the Apalachicola River. Bull. Geol. Soc. Amer., vol. v, 1894, p. 157.

Thickness:—The Choctawhatchee marl attains a thickness of over fifty feet in the vicinity of Redbay, Walton County, where it is exposed in some small ravines and on the banks of Mill Creek, near Holland P. O., Leon County, its thickness exceeds thirty feet. However, from observations elsewhere it appears probable that the average thickness is not more than twenty-five to thirty feet.

Physiographic Expression:—The Choctawhatchee marl rises to the surface in a belt from six to over twelve miles in width, extending from southern Walton County eastward to Leon County. While the topography of this area is in part determined by the younger formations, the influence of the soft marls is seen in the deep narrow valleys. The slopes are everywhere steep and the small streams often head in springs which emerge near the upper surface of the Choctawhatchee marl. North and west of Crestview, the surface is characterized by similar narrow valleys, but the marls are so effectually concealed by younger sands and clays that where present they probably have very little influence upon the configuration of the surface.

Paleontologic Characters:—The Choctawhatchee marl contains an abundant fauna consisting of nearly 200 species. The most numerous fossil is a small bivalve, *Mactra* (*Mulinia*) *congesta*, and associated with it are various other mollusca—one of the most characteristic being the gastropod *Ecphora quadricostata*. Other prominent fossils are: *Conus adversarius, Fusus equalis, Crucibulum constrictum, Pecten eboreus, Venus rileyi, Arca incile, A. idonea, Cardium acutelaqueatum, C. robustum, Carditamera arata*, and various species of *Turritella, Dentalium*, and others.

Structure: — The Choctawhatchee marl presents no marked peculiarities of structure. It rises to a height of over fifty feet above tide along its inner margin and dips gently seaward beneath the younger formations which border the coast. Probably the formation shared in the slight deformation which occurred during the late Tertiary or early Quaternary; but the exposures are so limited that no satisfactory evidence of folding was observed.

Local Details:—On the west bank of Choctawhatchee River, about one mile southeast of Redbay, there are numerous exposures of bluish-gray Miocene marl which probably have an aggregate thickness of over thirty feet. The slope above the outcrops of marl is covered by sandy loam, and shows scattered boulders of ferruginous sandstone resembling the sandstone of the Lafayette, observed elsewhere in Walton County and in some of the counties to the eastward. The marl at this locality is rather clayey and contains many fossils. The following species[1] were collected on the "Anderson" farm.

Locality:—Bluff, John Anderson's farm, one mile south of Redbay, Florida.

Turritella variabilis Conrad.
Dentalium attenuatum Say.
Arca staminea Say.
Pecten cf. eboreus Conrad.
Pecten madisonius Say.
Crassatellites melinus Conrad.
Chama arcinella Linn.[1] (Jackson bluff var.)
Cardium acutilaqueatum Conrad.
Venus rileyi Conrad.

Horizon:—Miocene—Jackson's bluff, Coe's mill, upper bed of Alum Bluff.

Miocene shell marl was encountered in a well drilled for the Southern States Lumber Company near Cantonment. A complete log of this well was furnished by Frank Sutter, driller, but unfortunately the samples of materials penetrated is incomplete. In a "greenish clay" at a depth of 500 feet, the following fossils[2] were obtained.

Locality:—Oil boring of Southern States Lumber Co., midway between Muscogee and Cantonment, Escambia County, Fla.

Sample 500 feet from surface.

Conus pygmaeus Reeve.
Arca idonea Conrad, young.
Lucina chrysostoma Philippi.
Cardium robustum Sol.
Venus campechiensis var. quadrata Dall.
Macrocallista maculata Linn.

Geologic Horizon:—At least two horizons are represented, one of which is Miocene.

Locality:—Oil boring of Southern States Lumber Co., midway between Muscogee and Cantonment.

The fossils listed below were obtained in a fifty-foot bed of "green sand" at a depth of 670 feet. Another sample was obtained in a "green clay" from a depth of 890 feet. This sample contained several fossils.

---

[1] Identified by T. Wayland Vaughan.

[2] Identified by T. Wayland Vaughan.

670 feet from surface.[1]

Conus pygmaeus Reeve.
Cancellaria smithii Dall var.
Astyris profundi Dall var.
Neverita duplicata Say.
Arca idonea Say.
Cardium laqueatum Conrad.

Geologic Horizon:—Fossils mixed, Miocene represented.

890 feet from surface.[2]

Natica sp. (fragment).
Cardium laqueatum Conrad.
Venus large sp. (fragments).

Geologic Horizon:—Miocene fossils present.

Dr. Vaughan identified the fossils listed above and his conclusions which are given below serve to indicate that the only value to be attached to this record is the presence of Miocene marls.

Additional Remarks: — "This record is entirely untrustworthy. Fossils from above have apparently tumbled down into the bore hole, and probably those from three horizons are commingled. Furthermore, the indicated thickness of the Miocene is suspiciously great."

Bluish green shell marl was reported on the east bank of Holmes Creek four miles south of Vernon and similar material was encountered in a well at Miller's Ferry beneath twenty feet of sand and clay.

The Choctawhatchee marl was observed by Dall, Foerste, Vaughan and others at various places on the Chipola, Apalachicola and Ocklocknee Rivers. The sections recorded by Dall[1] on the Chipola River are as follows:

The section here was measured with a steel tapeline on the left bank of the Chipola River, Calhoun County, Florida, at the bluff about 200 feet north of the spring, which here flows from a wooden pipe.

Section at Abes Spring.

1.	Superficial sands, about	4 feet.
2.	Reddish and yellowish streaked sands	30-32 feet.
3.	Gray aluminous clay	19 feet.
4.	Chesapeake gray marl to water (variable)	7 feet.
	Total thickness above water	62 feet.

In detail these strata have the following composition:

Number 1.—Pale, yellowish gray, incoherent sand, such as might be deposited by a river during seasons of high water, less like beach-sand than the analogous material at Alum Bluff.

---

[1] Identified by T. Wayland Vaughan.

[2] Identified by T. Wayland Vaughan.

[3] Dall, Wm. H., and Stanley-Brown, Joseph. Cenozoic Geology along the Apalachicola River, Geol. Soc. Am., Bull. vol. v, 1894, pp. 160-161.

Number 2.—Of the same character as number 3 of Alum Bluff. The material is generally a little coarser and the gravels a little larger, and there is also greater heterogeneity in structure.

Number 3.—Same as number 4 (aluminous clay) of Alum Bluff.

Number 4.—Chesapeake, just as at Alum Bluff.

Darlings Slide and Section.—On the Chipola River, a mile or more north of Abes Spring, is a "slide" where timber is cast into the river for the construction of rafts, which are floated down the river to the mills at Apalachicola, on the Gulf. This place is locally known as Darling Slide, and is a very steep natural bank, affording an excellent section, though somewhat obscured by weathering and the friction of the enormous logs which are rolled over it. It is on the left bank, and the bank opposite is low and apparently of alluvium.

Section at Darling Slide.

4.	Superficial sands	3 feet.
3.	Reddish and yellowish streaked sands	18-20 feet.
2.	Gray aluminous clay (presence or thickness uncertain)	27 feet.
1.	Chesapeake marl to water (variable)	
	Total thickness above water	50 feet.

The composition of the several beds is as follows:

Number 1.—Pale yellowish gray incoherent sand, such as might be deposited by a river during floods—less like beach-sand than the analogous material at Alum Bluff.

Number 2.—Of the same character as number 3 of Alum Bluff. The material is generally coarser and the gravels a little larger. There is also greater heterogeneity in structure.

Number 3.—The conditions were unfavorable for determining the presence or thickness of the gray aluminous clay, but from the fact that it is well exposed with sharp contacts at Abes Spring, but a short distance south, and, together with the Chesapeake, makes up 27 feet of thickness, it is reasonable to suppose that it forms part of the 27 feet assigned to 3 and 4.

Number 4.—Chesapeake marl, in every respect the same as that formation found at Alum Bluff.

It is notable that nothing below the Chesapeake is visible, although it has been stated that the Chipola beds exist under the gray marl. This can only be an assumption, since, with the water, as we were informed, within a foot of its lowest stage nothing of the sort was visible nor does the stream show any material such as would be washed out of the older Miocene beds, if present. The principal fossil here, as at Alum Bluff, is *Mactra congesta,* Conrad, with which are associated *Venus mercenaria,* L., and *Turritella variabilis,* Conrad The beds above the Chesapeake appear to be destitute of fossils.

From Dall's discussion in an earlier part of this paper he appears to have regarded No. 1 of each section as Pleistocene and No. 2 as Pliocene,[1] and he correlates the "aluminous clay" with the Pascagoula formation and the "Chesapeake" (Choctowhatchee) marl with the Chesapeake of Virginia and Maryland.

---

[1] Ibid. pp. 169 and 170.

The contact line between 1 and 2 of the above section which was inaccessible at the time Dall's section was made has recently been determined by E. H. Sellards, who has supplied the following section:

5.	Loose medium coarse pale yellow sand resembling the top sands at Alum Bluff	11 feet.
4.	Coarse cross bedded red sands containing pebbles up to ½ inch in length	14 feet.
3.	Covered and sloping	8 feet.
2.	Dark colored micaceous clays	4 feet
1.	Gray fossiliferous marl to the water edge	25 feet.
		62 feet.

On the south bank of Four-Mile Creek, about three-quarters of a mile north of Clarksville, in Calhoun County, the following section was observed:

Covered by sandy loam	30 feet.
Bluish gray marly clay (plastic)	14 feet.
Very fossiliferous bluish gray shell marl, to water	4 feet.

The fossils observed here were the same as those which characterize the Choctawhatchee marl at Alum Bluff and elsewhere. Associated with the shells were a number of dark colored fragments of bones which are locally regarded as an indication that the deposit might prove valuable as a fertilizer. Even though these fragments may be phosphatic, they are not sufficiently abundant to be of economic value.

At Alum Bluff, on the Apalachicola River, the Choctawhatchee marl was observed by Dall. At this locality the "aluminous clay" has a thickness of twenty-four feet, and is immediately underlain by thirty-five feet of sandy shell marl which contains an abundant Miocene fauna. There does not appear to have been any abrupt physical break between the fossiliferous shell marl and the non-fossiliferous "aluminous clay," though the latter appears to have a larger percentage of clay than the former. Both have the same color and both are arenaceous; but the one is highly fossiliferous and the other barren of animal remains except for occasional obscure traces of gastropods and bivalves.

Toward the north the shell marls thin to scarcely more than five feet. On the east side of the Apalachicola River, Mr. Burns[1] traced the Miocene marls from about five miles above Bristol southward about thirteen miles to where it finally disappears.

The Choctawhatchee marl is exposed at various points on the Ocklocknee River.

---

[1] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, p. 124.

About sixteen miles west of Tallahassee, in Sec. 9, T. 1 S., R. 2 W., Dr. Vaughan[1] found an exposure of Miocene marl. The outcrop is on Duggar Creek, near the house of W. C. Allen; the material contains the same fauna and is lithologically similar to the Choctawhatchee marl at Alum Bluff.

On the farm of Jas. R. Harvey, one mile west of Holland P. O., a bed of very fossiliferous marl was encountered in a well at a depth of twenty-eight feet. The section encountered in digging the well is:

Red ferruginous sand	10 feet.
Red and yellow sandy clay	8 feet.
Yellow Choctawhatchee marl becoming bluish gray below the surface, water-bearing	7 feet.

From the material obtained from this well, a few fossils[2] were collected and they serve to show the age of the marl.

Locality:—One mile west of Holland P. O., from well of Jas. R. Harvey.

Anguinella virginica Conrad.
Turritella variabilis Conrad.
Crucibulum auricula Gmel.
Crepidula costata Morton.
Crepidula convexa Say.
Arca incile Say.
Arca idonea Conrad.
Arca sp. indet.
Pecten eboreus Conrad.
Ostrea disparilis Conrad.
Plicatula marginata Say.
Anomia simplex Orb.
Crassatellites undulata Conrad.
Carditamera arata Conrad.
Venericardia granulata Say.
Lucina chrysostoma Meusch.
Phacoides multistriatus Conrad.
Phacoides cribrarius Say.
Chione ulocyma Dall.
Venus.
Mulinia congesta Conrad.
Mulinia contracta Conrad.

Near Black's saw mill on the banks of Mill Creek, the Choctawhatchee marl has a thickness of over thirty feet, but the exposures are poor. In the bed of the creek, the material ranges from blue to yellowish-gray in color, is not fossiliferous, but about twenty-five feet above the stream there is an exposure of about five feet of bluish gray shell marl containing fossils. From this bed a small collection was obtained, consisting of:[3]

Locality:—Mill Creek, one mile southwest of Holland P. O., Hugh Black's Sawmill.

Pecten n. sp.?
Venericardia tridentata Say.
Phacoides multistriatus Conrad.
Mulinia congesta Conrad.
Corbula inaequalis Say.

About one mile southwest of Holland P. O., similar shell marl was encountered in digging a mill race at Hugh Black's saw mill. According to statements made by Mr. James R. Harvey, this shell marl extends southward along the Ocklocknee River nearly twelve miles. At Jackson Bluff, about one mile southwest of Bloxham, the Choctawhatchee marl has a thickness of eight or ten feet. (See secs., p. 114). This locality was described by Dall[1] in 1894 and in 1900 the locality was visited by Vaughan[2] who collected the fossils listed by Dall[3] in his discussion of the Florida Miocene.

---

[1] Vaughan, T. Wayland. Unpublished notes.

[2] Identified by T. Wayland Vaughan.

[3] Identified by T. Wayland Vaughan.

Section at Jackson's Bluff.

Superficial sands	5 feet.
Bluish marl with *Mactra congesta*, Choctawhatchee	8 feet
Gray marly bed, with oysters and *Pecten*	22 feet.
Total thickness	35 feet.

Vaughan also collected from a yellowish sand representing a slightly higher stratum of the same bluff in the N. E. ¼ of Sec. 20, T. 1 S., R. 4 W., and he reports the occurrence of similar fossils in Sections 21 and 30, T. 1 S., R. 4 W.

The presence of *Pecten madisonius* in a collection of Pliocene fossils from the banks of the St. Johns River one-fourth mile below Nashua, Putnam County, suggests that Miocene may occur at that locality. The collection was made from a shell marl forming a bluff which rises about three feet above the river.

Samples of marl from a well at DeLand were examined by Dr. Vaughan and found to contain *Pecten* type of *madisonius* and *Chione* type of *cancellata*. From the presence of the *madisonius* type of *Pecten* the marl is believed to be Miocene.

Species of *Pecten eboreus* Conrad and *Pecten gibbus* Linn., together with *Ostrea haitiensis* Sowerby were also found about one mile above Caloosa on the Caloosahatchee River. The presence of these fossils is believed to indicate that the beds are Miocene; but this conclusion is held subject to revision in case subsequent investigations should result in the finding of larger collections which belong to some other period. This locality is of special interest because heretofore no Miocene has been reported so far south on the Gulf coast of the State.

---

[1] Dall, Wm. H., and Stanley-Brown, Joseph. Cenozoic Geology along the Apalachicola River. Geol. Soc. Am., Bull. vol. v, 1894, p. 158.

[2] Vaughan, T. Wayland. Unpublished notes.

[3] Dall, Wm. H., Wag. Free Inst. Sci. Trans., vol. 3, pt. 6, 1903, pp. 1596-98.

PLIOCENE.

CALOOSAHATCHEE MARL.

The existence of Pliocene beds in Florida was recognized as early as 1885, but the first published account is found in Heilprin's report, which was issued in 1887.[1] This writer gave a description of the shell marls exposed along the Caloosahatchee River, and referred them to the Pliocene.

> It will thus be seen that the relation of recent to extinct species is as 48 to 41, giving a very much higher percentage for living forms than obtains in any of the divisions of our recognized Miocene deposits, even the "Carolinian," which holds a position nearly equivalent to the so-called Mio-Pliocene of Europe. It becomes manifest that this most extensive Floridian exposure represents the Pliocene age—a circumstance interesting, apart from the general bearing which its presence has upon the geology of the State in particular, from the fact that it gives us the first unequivocal indication of the existence of marine Pliocene deposits in the United States east of the Pacific slope.[2]

To these beds Heilprin[3] gave the name Floridian. The name Caloosahatchee marl was applied by Dall to the Pliocene beds along the Caloosahatchee River and the streams entering Charlotte Harbor.[4] In 1887 the shell marls on the Caloosahatchee River was described by Dall,[5] who agreed with Heilprin in referring them to the Pliocene. In subsequent papers[6] by the same author these marls were called the Caloosahatchee beds, from the type locality on the river of that name. Thus, Dall's Caloosahatchee beds include the Floridian beds of Heilprin. The name proposed by Dall is retained for the Pliocene beds of the Caloosahatchee River and neighboring streams, but since these beds are largely marl the formation is here called Caloosahatchee marl.

The type locality of the "Arcadia marl"[7] is on Mare Branch, a tributary of Peace River, about six miles north of the town of Arcadia, and with this marl is included an oyster marl which Dall described from a locality about three miles north of the wagon bridge at Arcadia.[1] The close resemblance of these marls to the Caloosahatchee marl seems to warrant regarding them as a phase of that formation, thus making "Arcadia marl" a superfluous term in geologic nomenclature.

---

[1] Heilprin, Angelo, Explorations on the west coast of Florida. Wag. Free Inst. of Sci. Trans., vol. i, 1887, pp. 26-33.

[2] L. C., p. 31.

[3] Heilprin, Angelo, Explorations on the west coast of Florida. Wag. Free Inst. of Sci. Trans., vol. i, 1887, p. 32.

[4] Dall, Wm. H., Notes on the Geology of Florida; Am. Jour. Sci., vol. xxxiv, 1887, p. 169.

[5] Ibid. p. 161-170.

[6] Dall, Wm. H., The Neocene of North America, U. S. Geol. Survey Bull. No. 84, 1892, pp. 140-149, and Wagner Free Inst. Sci. Trans., vol. iii, pt. vi, 1893, pp. 1603-05.

[7] Dall, Wm. H., The Neocene of North America, U. S. Geol. Survey Bull. No. 84, 1892, pp. 131-132.

Stratigraphic Position:—The contact of the Caloosahatchee marl with the underlying Miocene has not been observed, but there is a considerable change in fauna between the Miocene which is probably due to physiographic changes which may have permitted the erosion of the Miocene beds before the beginning of the Pliocene deposition. The contact of the Caloosahatchee marl with the overlying Pleistocene is commonly marked by an erosion unconformity. Where this unconformity is not noticeable it has been masked by reworking of the Pliocene marl by the waves of the Pleistocene sea.

Lithologic Character: — The Caloosahatchee marl consists of a light-gray shell marl which is often interbedded with nearly pure sand. The matrix is usually very calcareous, but locally it consists of sand and even in the most calcareous portion sand is abundant. The shells are remarkable for their excellent state of preservation and their abundance in certain layers makes it possible to secure excellent collections.

Thickness:—It is difficult to form a correct estimate of the thickness of the Caloosahatchee marl, but its maximum is probably about twenty-five feet. Single exposures seldom exceed five to ten feet, and the average thickness is probably less than eight feet. On the whole the Caloosahatchee marl is probably to be regarded as thin, though it may thicken considerably toward the central portion of the peninsula and toward the southern end of the State.

Physiographic Expression:—The Caloosahatchee marl occupies a region of such low altitude that it has been only slightly dissected. In fact, with the exception of the valleys of the streams entering Charlotte Harbor the surface of the region underlain by this formation is an almost unbroken plain. While this is doubtless in part due to the later deposit of Pleistocene sand, it is doubtful if the surface of the Caloosahatchee marl has ever been greatly eroded.

Paleontologic Character:—Dall's list of Pliocene fossils obtained from the Caloosahatchee marl in Florida includes 639 species, of which 256 species are not known from other States. The marine formations of this period are very fossiliferous, and the fauna as a whole is such as might be expected in shallow water. Since the Caloosahatchee marl was the only Pliocene formation known in Florida at that time this number may be taken as a measure of the species recognized as belonging to it. Dall[1] has also noted the fact that the upper beds of the Caloosahatchee Pliocene contain a fauna more closely related to living forms than the lowermost layers; and that the shoaling of the water permitted the formation of oyster reefs, and, finally, the influx of fresh water species of *Planorbis,* etc.

---

[1] Ibid. pp. 132-133.

Structure:—The dip of the Pliocene beds in Florida is usually very difficult to determine. The Caloosahatchee River crosses the Caloosahatchee marl at the type locality and thus affords a good opportunity for observing the attitude of the marl beds. Concerning these beds Dall says:[2]

> The uppermost strata of the Pliocene beds begin to appear above the level of the river at low water (during the dry season) about 24 miles due east from the shore of Charlotte harbor, and they dip to the eastward out of reach about 30 miles farther east. Their total measured breadth here is thus at least 30 miles and includes the whole of the elevated land between Lake Hickpochee and the point on the river above mentioned. In this distance there are not less than twenty visible but very gentle folds of the strata in the direction of the trend of the peninsula.

In a later paper Dall says of these same beds:[3]

> The Pliocene beds dip gently to the westward so that those portions near the sea are newer than those outcropping near the headwaters of the streams.

In discussing the Miocene the marls near Caloosa were doubtfully referred to that period. The Caloosahatchee marl is exposed at intervals from near this locality to the vicinity of Labelle, several miles farther up stream, where the Pleistocene appears. The fact that the Pliocene marls dip beneath the Pleistocene near Labelle may be explained by an easterly dip of the beds. The alternative hypothesis of a westerly dip would only be true in case the increase in altitude of the water surface was somewhat greater than the thickness of the Caloosahatchee marl. The actual rise in the water level between these localities as determined instrumentally varies with the stage of the river, but at mean low water, is probably less than five feet. Apparently the correct explanation is that the actual dip of these beds is in a general easterly direction instead of toward the west.

Aside from a slight tilting, the marls of the Caloosahatchee River have been gently folded so that they exhibit a series of low undulations with axes parallel to the general trend of the peninsula. The width of these arches is usually less than one-fourth of a mile; and they probably do not exceed fifteen feet in height. Elsewhere, no folding has been observed; but it is probable that the disturbance which produced the low arches on the Caloosahatchee was general and consequently the other Pliocene beds may exhibit the same structural features.

---

[1] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey Bull. No. 84, 1892, pp. 145-146.

[2] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey Bull. No. 84, 1892, p. 146.

[3] Dall, Wm. H., Wagner Free Inst. Sci. Trans., vol. iii, pt. 6, 1903, p. 1604.

Local Details: — There are numerous exposures of the Caloosahatchee marl between Labelle and Caloosa, on the Caloosahatchee River. Of this Pliocene rock Dall[1] says:

> On the Caloosahatchee, the strata may be divided into oyster-reef marl beds, conchiferous or Turritella marl, and layers of sand; which intergrade without distinction and have no invariable succession, but always grade into the shallow water fauna at the top, which is overlain by the Planorbis rock, and this in turn by post-Pliocene deposits which are seldom of great thickness.

At Labelle the Pliocene beds have a thickness of four feet beneath three feet of fossiliferous Pleistocene marl covered by three feet of sandy loam. At this locality the Caloosahatchee marl consists of calcareous sand containing a large number of Pliocene shells. One mile below Labelle the following section was observed:

Recent:	
Surficial soil and muck	3 feet.
Pleistocene or Recent:	
Banded marl varying from nearly black to yellow	1 foot.
Caloosahatchee marl:	
Gray clayey marl containing some nodules, very fossiliferous	4 feet.
Well stratified greenish gray clayey marl containing some fossils	2 feet
Total	10 feet.

One-half mile below the last locality the Caloosahatchee marl has a thickness of about seven feet and is abundantly fossiliferous, containing many large Pectens, ostreas and gastropods. About one mile farther down stream, a conspicuous oyster bed about one foot thick rises above the level of the river. Five miles below Labelle, the following section was examined:

Concretionary calcareous marl very fossiliferous	3 feet.
Oyster bed characterized by a large *Ostrea sculpturata* and *Pecten eboreus*	2 feet.
Soft white clayey marl	4 feet.
Total	9 feet.

The oyster bed is exposed at intervals for several miles.

---

[1] Dall Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. No. 84, p. 147, 1892.

In addition to the Caloosahatchee marl already described, Dall mentions several localities on other streams entering Charlotte Harbor:[1]

> Near the north end of Charlotte harbor a small creek comes in from the east called Alligator Creek. Here Mr. Willcox found an extension of the Caloosahatchee beds. The banks are about 12 feet high, the upper half being pure sand; the lower half contains fossils of Pliocene age, mollusks, barnacles, and flat Echinidae. They differ from the Caloosahatchee deposits in being in pure sand instead of marl as a matrix. The upper half of the fossiliferous stratum shows the shallow-water fauna, with its usual partial admixture of strictly Pliocene extinct species. Some parts of the bed are united by siliceous cementation into a hard rock. * * * The banks are higher here than on the Caloosahatchee, being 25 feet at the highest point, but the difference is chiefly of unfossiliferous marine sand 12 feet deep. Then comes about 2 feet of shallow water fauna with some Pliocene species, below which is a hard limestone stratum 2 or 3 feet thick, beneath which is a bed of conchiferous-marl, like that of the Caloosahatchee. There are slight differences in the fauna, such as might be expected at points 20 miles apart. * * *
>
> Here (on the Miakka River) Mr. Willcox found a bed of lime rock at the sea level with uncharacteristic species poorly preserved. Above the lime rock are beds of shell marl considerably mixed with sand. In this deposit was collected about forty species of shells, of which about 10 per cent were extinct Pliocene species. This bed seems to have fewer extinct species than the Caloosahatchee marls and may be regarded as a little younger, perhaps corresponding to the Planorbis rock, which seems to be absent on the Miakka.
>
> Along Rocky Creek, which falls into Lemon Bay, near Stump Pass, in about latitude 26° 55′ west from the Miakka, a bed of *Venus cancellata* rises to about a foot above the water, or in many places forms the bed of the stream. It is probably the upper shallow water layer of the Pliocene, or *Cerithidea scalata* Heilprin, a Pliocene species, has been found nearby on the beach of the bay.
>
> On Peace Creek there are no banks high enough to afford a section, and no trace of Pliocene yet observed up to 3 miles above Fort Ogden.

Farther north, on Peace Creek, the Caloosahatchee beds appear at Shell Point, 3 miles above Arcadia, as previously described; and I was informed that the same bed occurs on Joshua Creek, near Nocatee, and at a point on Peace Creek 6 miles below the works at Arcadia, between that place and Fort Ogden. The same oyster bed is conspicuous in the banks of a small stream just north of the railroad station at Zolfo Springs. This stream, a feeder of Peace Creek from the east, has cut quite a deep gully and the oyster bed occurs in the vertical sides about 2 feet, or possibly less, above the water when the latter is low, as in January, when I observed it. Above the oyster bed, the elevation cut by the stream is composed of some 20 or 25 feet of yellow sand, with a foot or two of the white sand covering it. Some portions of the yellow sand here, as at Shell Point, are quite indurated and stand vertically like rock. The section can be well observed from the railway culvert.

Considerably east of Peace Creek beds of marl containing "large clams" have been reported to Mr. Willcox as occurring on the banks of Arbuckle Creek. Something of the same sort on the Kissimmee River, near Fort Kissimmee, was mentioned to me by prospectors at Bartow who had visited that locality. Both these marl beds are likely to prove to be Pliocene.

---

[1] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey Bull. No. 84, 1892, pp. 147-148.

The oyster marl which occurs on Peace River about three miles above Arcadia has been correlated with the Caloosahatchee marl.[1] Dall's section is:

1.	Humus and white sand	3-5 feet.
2.	Yellow sand (indurated)	3 feet.
3.	Oyster marl (in part subaqueous)	2-4 feet.

Nos. 1 and 2 of this section are doubtless Pliocene.

The "Arcadia marl," which was considered by Dall to be slightly older than the Caloosahatchee marl, has the following section:[2]

1.	Humus and white sand	1½- 6 feet.
2.	Yellow sand	6 -10 feet.
3.	Peace Creek bone bed, phosphatized rock with bones (about)	1 foot.
4.	Arcadia marl (yellowish sandy marl to water's edge)	3 feet.
	(The same, under water), about	3 - 6 feet.

The "Peace Creek bone bed" is probably to be correlated with the Alachua clay, and the first and second members of the section are doubtless Pleistocene.

NASHUA MARL.

During the progress of the field work for this report, collections of fossils were obtained which indicate that Pliocene marls are extensively developed in the valley of the St. Johns River, and a bed of similar marl near Daytona has been referred to the same period. These beds have certain faunal elements which distinguish them from the other Pliocene beds of Florida; and, hence, they are given a distinct name. They are here designated the Nashua marl, from a locality on the St. Johns River, where they are best exposed. Further study may result in uniting all of the marine Pliocene of Florida under a single name; but for the present it appears desirable to avoid hasty correlation by the use of local names for the beds of different localities, especially where conditions governing deposition appear to have been unlike.

Stratigraphic Position:—The Nashua marl is thought to rest unconformably upon the Miocene at DeLand; but this opinion lacks confirmation, as the collections from that locality have not been studied in sufficient detail to determine the exact age of the beds. At various localities, the contact between this formation and the overlying Pleistocene sand has been observed and it is everywhere marked by a distinct unconformity. The Pleistocene beds rest upon an undulating surface of the Nashua marl, which is clearly due to erosion, and the contrast between the fossiliferous marl and the overlying barren sands helps to emphasize the break between the two.

---

[1] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey Bull. No. 84, 1892, p. 132.

[2] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey Bull. No. 84, 1892, p. 131.

Lithologic Character:—The Nashua marl bears a strong lithologic resemblance to the Caloosahatchee marl. There is the same alternation of sand beds with shell marl. The matrix of the Nashua marl, while usually calcareous, is always more or less sandy and sometimes consists of nearly pure sand. The shells are commonly well preserved though locally a marl consisting of broken and eroded fragments of shells is not uncommon. However, the organic remains are so well preserved that it is easy to obtain good collections of fossils from this formation.

Thickness:—The Nashua marl is much thinner than the Miocene strata. This fact, together with its distribution beneath the lowlands near the coast, indicates that the Pliocene submergence was less extensive than the Miocene; and the presence of shallow water fossils shows that the Pliocene sea did not attain any great depth over that part of the State where the marine beds are now exposed. The Nashua marl is seldom more than six or eight feet thick, but locally it attains a greater thickness. A series of samples of sand and marl from a well at DeLand indicates that at that locality this marl has a thickness of about thirty-two feet.

Physiographic Expression:—The Nashua marl occupies the St. Johns Valley, where it underlies a broad terrace bordering the stream. It probably occurs beneath the plain east of St. Johns River, but the overlying Pleistocene forms such a thick mantle that the Nashua marl has no influence on the topography. On the whole, this formation has little or no influence on the topography of the State.

Paleontologic Character:—The fauna of the Nashua marl is only imperfectly known, but it has been sufficiently studied to show that it resembles that of the Caloosahatchee marl. The most striking difference between the faunas of the two formations is the existence of certain species in the Nashua marl which occur in the "Waccamaw" fauna of the Carolinas, but are not known to be present in the Caloosahatchee marl. This affinity with the fauna to the north suggests the existence of a cold current along the Atlantic coast which permitted a southward migration of the "Waccamaw" fauna. The lack of exposures in the south-central portion of the peninsula prevents the tracing of the connection between the two formations and the determination of the limits of the southward migration of the species from the "Waccamaw" fauna.

Structure:—The Nashua marl is exposed at only a few localities in the St. Johns Valley and it is difficult to form any definite idea concerning its structure. It has probably been subjected to the same deformation as the Caloosahatchee marl, but the isolated exposures afford no opportunity to observe evidences of folding. The dip is doubtless seaward and it is probably very slight.

Local Details:—In the St. Johns Valley there are a number of exposures of the Pliocene marl which have been designated the Nashua marl. At the type locality, one-fourth mile south of Nashua, Putnam County, there is an exposure of five feet of white sand, resting unconformably upon about fifteen feet of white shell marl. From this locality was obtained the list of fossils given below:[1]

Terebra protexta Conrad.
Terebra dislocata Say.
Terebra concava Say.
Conus marylandicus Green.
Oliva literata Lamk.
Olivella mutica Say.
Marginella pardalis Dall.
Volutella amiantula Dall.
Fulgur maximum Conrad.
Eupleura miocenica var. intermedia Dall.
Murex pomum Linn.
Ilyanassa porcina Say.
Ilyanassa isogramma Dall.
Ilyanassa granifera Conrad.
Nassa scalaspira Dall.
Anachis avara var. calossaensis Dall.
Turbonilla.
Eulima.
Cerithiopsis greeni C. B. Ads.
Crucibulum auricula Gmel.
Crepidula convexa Say.
Natica (Cryptonatica) pusilla Say.
Littorina irrorata Say.
Dentalium carolinense Conrad.
Arca (Noetia) limula var. platyura Dall.
Arca campyla Dall.
Ostrea virginica Gmel.
Pecten madisonius Say.
Anomia simplex Orb.
Crassinella lunulata Conrad.
Crassinella acuta Dall.
Phacoides tuomeyi Dall.
Phacoides multilineatus T. and H.
Divaricella chipolana Dall var.?
Cardium robustum Sol.
Venus tridacnoides Lam.
Dosinia, young—*D. elegans* Conrad?
Chione cancellata Linn.
Gemma magna Dall.
Pitaria? young.
Mulinia congesta Conrad.
Mulinia congesta var. triquetra Conrad.
Corbula cuneata Say.

Geologic Age:—"Pliocene, the presence of *Pecten madisonius* suggests the presence of Miocene in the same bluff. The fauna has an additional interest in containing species found in the 'Waccamaw beds,' but not in the Caloosahatchee." (Vaughan.)

One-half mile above the Atlantic Coast Line Railroad bridge over St. Johns River in Putnam County, there is a bluff which rises from three to eight feet above high water. At this locality, the Pliocene Nashua marl is well exposed and abundantly fossiliferous. Dr. Vaughan's list of fossils collected from this locality follows:

---

[1] Determined by Dr. Vaughan.

Locality:—One-half mile above A. C. L. bridge over St. Johns River, Putnam County, Fla., vertical cliff three feet to eight feet above high water level.

Tornatina canaliculata Say.
Urosalpinx perrugatus Conrad.
Astyris lunata Say.
Anachis.
Anachis.
Scala.
Crepidula convexa Say.
Rissoina chesneli Mich.
Arca campyla Dall.
Ostrea.
Modiolus.
Crassinella lunulata Conrad.
Carditamera arata Conrad.
Phacoides multilineatus T. and H.
Lucina.
Cardium oedalium Dall.
Cardium robustum Sol.
Chione cancellata Linn.
Dosinia elegans Conrad.
Macrocallista nimbosa Sol.
Semele purpurea Gmel.?
Mulinia lateralis Say? yo.
Corbula cuneata Say.

Geologic Horizon:—Pliocene.

About one-half mile south of De Leon Springs in Volusia County the following section was examined:

White sand, Pleistocene or Recent	4 feet.
Unconformity, yellowish brown sand and clay unassorted near the top but grading downward to well stratified clay, Pleistocene	7 feet.
Unconformity, yellow to white shell marl, Nashua marl	6 feet.
Total	17 feet.

At one point the clay extends downward into the Pliocene marl in a channel two feet across and four feet deep.

The names of a few fossils obtained from DeLeon Springs are given by Dall[1] in his list of Florida Miocene species.

Dall's list contains:

**Crepidula aculeata* Gmelin.
Ostrea sculpturata Conrad.
Carditamera arata Conrad.
Mulinia congesta Conrad.

It will be noticed that this list includes only four species and the first (*Crepidula aculeata,* Gmelin) is marked by an asterisk (*) in Dall's table to indicate that it is believed to survive to the recent fauna. Of the other three, one, *Ostrea sculpturata,*[2] is known from the Florida Pliocene of the Caloosahatchee River, Alligator Creek and Shell Creek, while another, *Carditamera arata,* is known from the same beds and from an additional locality. Both of these species are also known from the Pliocene fauna of the "Waccamaw beds" of the Carolinas. This leaves but one species, *Mulinia congesta,* of Dall's list which is not known from the Florida Pliocene. A recent collection from De Leon Springs contained the following species and these show that there are beds of Pliocene as well as Miocene represented in the section. The determinations were made by Vaughan, and his comment upon the list is appended.

---

[1] Dall, Wm. H., Tertiary Fauna of Florida, Wag. Free Inst. Sci., Trans., vol. iii, pt. 6, 1903, pp. 1596-1598.

[2] Ibid, pp. 1605-1614.

Locality:—One-half mile (+) south of De Leon Springs Station, Volusia County, Florida. Eleven to seventeen feet below surface.[1]

Marginella contracta Conrad.
Terebra dislocata Say.
Oliva literata Lam.
Melongena corona Gmel.
Crepidula aculeata Gmel.
Crepidula convexa Say.
Crepidula plana Say.
Cryptonatica pusilla Say.
Arca transversa Say.
Arca ponderosa Say.
Arca limula var. platyura Dall.
Arca plicatura Say.
Pecten gibbus Linn.
Carditamera arata Conrad.
Venericardia tridentata Say.
Phacoides multilineatus T and H.
Phacoides waccamensis Dall.
Phacoides radians Conrad.
Cardium robustum Solander.
Cardium isocardia Linn.
Venus campechiensis Gmel.
Chione cancellata Linn.
Mulinia lateralis Say.
Corbula inaequalis Say.

Geologic Horizon:—"Pliocene (Compare Dr. Dall's previous reference to Miocene at De Leon Springs, Wag. Free Inst. Sci.)"

On the east side of the St. Johns River, about five miles north of the Atlantic Coast Line Railroad bridge in Volusia County, there is a low exposure of sandy loam, sand and marl. The upper member consists of about two feet of light colored sandy loam which passes by gradual transition to a coarse-grained gray sand. Beneath this sand, and probably separated from it by an unconformity, is a bed of light green clayey marl containing many well preserved shells. From this locality was obtained the fossils listed below. The Pliocene age of the marl is inferred from the presence of *Cardium oedalium.*

Locality:—East side of St. Johns River, five miles below the Sanford Railroad bridge.[2]

Tornatina canaliculata Say.
Olivella mutica Say.
Fulgur pyrum Dillwyn.
Fulgur perversum Linn.
Nassa elevata Say.
Nassa vibex Say.
Crepidula fornicata Say.
Nucula proxima Say.
Arca transversa Say.
Mytilus venustus Linn.
Phacoides multilineatus T. and H.
Cardium oedalium Dall*
Laevicardium serratum Linn.
Anomalocardia caloosana Dall.
Venus campechiensis Gmel.
Chione cancellata Linn.
Tellina declivis Conrad.
Corbula contracta Say.
Mulinia lateralis Say.
Pholas costata Lam.

Geologic Horizon:—Probably Pliocene, inferred from the presence of *Cardium oedalium.*

---

[1] Determined by Dr. Vaughan.

[2] Identifications by Dr. Vaughan.

About 300 yards farther north and on the same side of the river a thin bed of gray limestone appears in places unconformably above the marl, and in other places the overlying sand is partially indurated. This limestone is probably of Pleistocene age.

About two miles north of the first locality, an exposure of shell marl one-half foot thick is capped by a deposit of clay and sand which is probably alluvial. From this locality a few species[1] were obtained. They include:

Locality:—East side of St. Johns River, seven miles below the railroad bridge near Sanford.

Arca campyla Dall.
Crassinella lunulata Conrad.
Phacoides multilineatus T. and H.
Chione cancellata Linn.
Transennella caloosana Dall.
Anomalocardia caloosana Dall.
Semele.
Abra aequalis Say.
Corbula contracta Say.

Geologic Horizon:—Probably Pliocene.

From a well near Kissimmee, Dr. Vaughan obtained a sample containing the fossils listed below. They show the existence of Pliocene beds at a depth of 150 feet, and under the head of Pleistocene lists of fossils are given which show the post-Pliocene beds at Kissimmee are at least 100 feet thick.

Locality:—From well of Mary Boss, on island in Lake Tohopekaliga, about three miles from Kissimmee, depth 150 feet.

Tornatina canaliculata Say.
Olivella mutica Say.
Marginella fragment.
Scala lineata Say.
Turritella subannulata Hpn.
Turritella apicalis Hpn.
Crucibulum auricula Gmel.
Dentalium caloosaense Dall.
Cadulus quadridentatus Dall?
Nucula proxima Say.
Leda, n. sp., also Shell Creek Pliocene.
Pecten gibbus Linn.
Anomia simplex Orb.
Venericardia tridentata Say.
Phacoides, worn specimens.
Callocardia sayana Conrad.
Chione cancellata Linn.
Gemma trigona Dall.
Gemma sp.
Parastarte triquetra Conrad.
Ensis, fragment.
Mulinia lateralis Say.
Balanus sp.

Geologic Horizon:—Pliocene.

ALACHUA CLAY.

The non-marine Pliocene of Florida includes the Alachua clay, which is apparently a terrestrial or fresh-water deposit. It was described by Dall[2] in 1892:

---

[1] Identifications by Dr. Vaughan.

[2] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, p. 127.

> Terrestrial Fauna, the Alachua Clays:—Later in this essay I shall endeavor to indicate all that is known to date of writing of the marine Pliocene beds of Florida, but there is another formation to be spoken of which has been referred by some authorities to the Upper Miocene, though regarded by others as late Pliocene or even Pleistocene. This comprises the deposits of clay containing bones of extinct mammalia which, in my report to the Director of the U. S. Geological Survey in 1885, I termed the Alachua clays.

The report mentioned above does not appear to have been published, and hence the quotation probably contains the first published reference to these clays. With these beds are included the "Peace Creek bone bed" of Dall,[1] which appears to be a local phase of the formation which may have been eroded and redeposited in its present position.

Stratigraphic Position: — The Alachua clay is known to occupy depressions such as sinks and gullies in the Oligocene and probably also in the Miocene beds. Observations made by Dall along the banks of Peace River have established the fact that a bone bed ("Peace Creek bone bed") which he correlates with the Alachua clay, rests upon older Pliocene beds.[2] The relation between the Alachua clay and this bed on Peace Creek has not been observed, but they are believed to be lacustrine or fluviatile deposits which may have been formed at about the same time. The Alachua clay is also thought to be contemporaneous with a part of the Caloosahatchee and Nashua marls.

Lithologic Character:—The Alachua clay consists of blue to gray sandy clay which weathers to light yellow or red from the presence of iron oxide. There is usually sufficient clay to give the material a distinct plasticity, and sand is commonly present in considerable quantities. The weathered material is frequently more or less concretionary as a result of the aggregation of the iron oxide. The formation is nearly destitute of fossils except in a few localities where it is filled with vertebrate remains.

Thickness: — The Alachua clay represents accumulations in depressions of the surface of the Oligocene beds, and hence the thickness is variable. It is known to have a thickness of fifteen feet and the maximum may be much greater. It is difficult to estimate the average thickness, but it is probably not less than ten feet.

Physiographic Expression:—The Alachua clay has no marked effect upon the topography; but from its occurrence in depressions in the underlying rocks it probably helps to diminish the relief. Locally this formation is represented by low ridges which rise above the general level.

---

[1] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, pp 130-131.

[2] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, pp. 131-132.

Paleontologic Character:—The Alachua clay contains a few obscure remains of what appear to be fresh water shells, but the state of preservation does not admit of their identification. Locally, vertebrate remains are abundant, and it was this fauna which first called attention to the formation. On a subsequent page a list of the vertebrate fossils is given.

Structure:—The Alachua clay appears to have undergone no disturbance since its deposition, and hence it presents no structural features of interest. Its accumulation in local depressions prevents its having any general attitude, and the dips observed, while slight, are variable.

Local Details:—Sections of the Alachua clay are to be seen in the vicinity of Gainesville and Archer, Alachua County. Near the wagon road, one mile northwest of Gainesville, there is an exposure in an old mill race. At this locality the outcrop probably does not exceed four feet, but farther up the hill to the east similar material is exposed in a ditch where it has a thickness of about fifteen feet, and is overlain unconformably by about four feet of white Pleistocene sand. The basal portion of this section, which evidently represents one of the localities mentioned by Dall[1] is a greenish gray clay containing a large admixture of coarse sand. It changes to a very light yellow when exposed to the weather; and, in this respect, agrees with the material on the hillside above. The complete section at this locality is:

Light gray sand, Pleistocene	4 feet.
Erosion unconformity.	
Blue sandy clay, weathering light yellow	15 feet.
Covered	15 feet.
Blue sandy clay	4 feet.
Total	38 feet.

About two and a half miles west of Gainesville, there is another exposure of Alachua clay, consisting of a light-yellow clayey sand which is very plastic when wet, but hardens into a moderately firm rock on drying. The thickness of the exposure is not less than fifteen feet, and it is covered by a deposit of sandy loam of Pleistocene age, which rests unconformably upon the clays at this locality. Thin partings of sand are common; the upper four feet of the section contains many small calcareous nodules; and near the middle some casts of what appeared to be fresh water bivalves were noted.

---

[1] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, p. 128.

Dall[1] mentions the occurrence of vertebrate remains on Peace Creek, the Caloosahatchee River, and in Wakulla County. He also gives the following list of localities for the Alachua clay:

> . Among the localities to be noted are: In Alachua County, Mixon's farm, 10 miles south and 1½ miles east of the railway station at Archer; Hallowell's place, 10 miles north and 2 miles west of the station; a pond about one-fourth of a mile from the station; another in the vicinity of Mixon's, 2 miles northwest of the first; a ditch about 2½ miles west of Gainesville; a spot where the railway crosses the Santa Fe River, near Gainesville, 1 mile north of Gainesville, on the Newnansville road, in a ditch dug for a mill race; and Owen's, nearer the town. Other localities are: Clay Landing, on the Suwannee River, near Fort Griffin, Levy County; Rocky Creek (old Tampa Bay), Hillsboro County (*Bison latifrons*); Philip's quarry, Ocala, Marion County.

The fauna of the Alachua clay as given by Dall,[2] who secured the lists of fossils from Dr. Leidy, is as follows:

Rhinoceros proterus	From Archer.
Mastodon floridanus	
Megatherium sp.	
Auchenia major	
Auchenia minor	
Auchenia minima	
Cervus (*virginianus?*)	
Hippotherium ingenuum	
Rhinoceros proterus	From Mixon's, 10 miles east from Archer.
Mastodon floridanus	
Hippotherium ingenuum	
Hippotherium plicatile	
Auchenia major	
Elephas columbi	From Ocala, Marion County.
Equus fraternus	
Aychenia minima	
Machairodus floridanus	

The following specimens have been obtained from a bed which extends for miles along the banks of Peace Creek, DeSoto County, near Arcadia.

Tapirus americanus.
Elephas columbi.
Mastodon sp. (not *M. floridanus*).
Hippotherium ingenuum.
Equus fraternus.
Bison americanus.
Cervus virginianus.
Magalonyx jeffersonii.
Chlamydotherium humboldtii.
Glyptodon sp.
Hoplophorus euphractus.
Manatus antiquus.
Priscodelphinus sp.
Emys euglypha.
Trionyx sp.
Eupachemys sp.
Testudo crassiscutata.

---

[1] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, p. 128.

[2] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, p. 129.

Alligator mississipiensis, and a variety of fish remains, including teeth of *Carcharodon, Galeocerdo, Myliobates,* etc.

From the Pliocene beds of the Caloosahatchee were obtained:

Bison latifrons.	*Equus fraternus.*
Elephas columbi.	

After the death of Dr. Leidy, the completion of the descriptions of the Florida vertebrates was assigned to Mr. Lucas, who made the following changes in nomenclature:[1]

> The changes in nomenclature, for which the present writer assumes all responsibility, and the conclusions in regard to species may be briefly summed up as follows:
>
> *Rhinoceros proterus* Leidy is *Aphelops fossiger* (Cope) and *Rhinoceros longipes* Leidy is *Aphelops malacorhinus* (Cope).
>
> *Procamelus major* (Leidy) appears to be a valid species, while the specific identity of *Procamelus medius* and *P. minor* is not yet proven. The same may perhaps be said of *Mastodon floridanus,* but until other specimens of *Mastodon serridens* can be secured, *Mastodon floridanus* should undoubtedly be considered as distinct. *Hippotherium princeps,* in the opinion of the writer, rests on an abnormal tooth of *Equus major.*

It is interesting to note that the faunal similarity between the Alachua clay and the "Loup Fork beds" of the West is strengthened by the changes in nomenclature suggested by Mr. Lucas.

Loup Fork.	*Florida.*	*Equus Beds.*
	Glyptodon petaliferus Cope.	*Glyptodon petaliferus* Cope.
	Chlamydotherium humboldtii Lund.	*C. humboldtii* Lund.
Machairodus catocopis Cope.	*Machairodus floridanus* Leidy.	
*Rhinoceros (Aphelops). fossiger** Cope.	*Rhinoceros (Aphelops) proterus** Leidy.	
Rhinoceros (Aphelops) malacorhinus Cope.	*Rhinoceros (Aphelops) longipes* Leidy.	
Hippotherium occidentale Leidy.	*Hippotherium princeps* Leidy.	
	Equus major DeKay.	*Equus major* De Kay.
	*Mastodon floridanus** Leidy.	*Mastodon serridens** Cope.
*Pliauchenia vulcanorum** Cope.	*Pliauchenia major** Leidy.	
	Pliauchenia media Leidy.	
*Pliauchenia humphreysiana** Cope.	*Pliauchenia minor** Leidy.	

---

[1] Leidy, Joseph, Fossil Vertebrates from the Alachua Clays of Florida. Edited by Frederick A. Lucas, Wag. Free Inst. Sci., Trans., vol. iv, 1896, pp. 7 and 8.

A few of the other described species do not throw any light on the question of age. Those marked with an asterisk are not yet shown to be distinct from the corresponding species of the other horizons. It thus appears that six species are allied to or identical with as many of the Loup Fork horizon of the West, while four are characteristic of the Equus beds of the East, of Texas, and of South America. The epoch they represent is then probably between the two.

BONE VALLEY GRAVEL.

The deposits here called Bone Valley gravel have been described by both Eldridge[1] and Dall.[2] They comprise nearly all of the pebble phosphates now being mined in Florida, and the name is derived from a locality west of Bartow, where the beds are exploited on a large scale. The names formerly used for this formation varied somewhat with different writers. Eldridge designated the deposit as *land pebble phosphate,* while Dall called them simply *pebble phosphates.* Both writers distinguished between the Tertiary deposits of Pliocene age and the younger pebble phosphate which vary in age from Pleistocene to Recent.

That these beds were regarded by Dall as Pliocene will be seen from the following quotation:[3]

> A very large area in central and southern Florida was probably covered by this older marine Pliocene. There appear to be traces of it at Clay Landing and other points on the lower Suwanee River, and it is not unlikely that the whole great Suwanee swamp region may be underlain by it, as well as the DeSoto lake area. There are traces of it in the rocks of the upper Alefia, but farther to the west and north, on the Hillsboro,so far as known, if any of this rock was deposited, it has since been removed. I incline to the belief, however, that the Hillsboro region, from its relation to the great western anticline was not depressed below the sea during this part of the Pliocene. The "pebble phosphates" of the upper Alefia, like those of the Peace Creek basin, are, as far as yet observed, entirely of this rock, and on the Alefia researches hitherto made have failed to find the subsequent marine Caloosahatchee Pliocene represented.

There are both physiographic and lithologic reasons for thinking that these gravels are in considerable measure of fluviatile origin. They are situated in the valleys of streams and vary in altitude from less than twenty-five feet to nearly a hundred feet above tide. Lithologically, the formation is composed of very poorly assorted materials, such as clay and phosphate pebbles, which usually show some evidence of stratification. If the gravel beds were deposited during gradual submergence or emergence of the land, the variation in altitude might be explained by assuming that they were deposited along the margin of an advancing or receding sea. Unfortunately, for this theory, the poor assortment of the materials and the absence, locally, of distinct stratification point rather to fluviatile than marginal origin. It is, however, probable that some of the deposits were made in the margin of estuaries. The presence of such organic remains as bone fragments and sharks' teeth is readily explained by the fact that the phosphatic gravels were derived from older formations in which such materials occurred.

---

[1] Eldridge, Geo. H., Preliminary sketch of the phosphates of Florida, Am. Inst. Mng. Engrs., vol. xxi, 1893, pp. 196-231.

[2] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, pp. 137-138.

[3] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, pp. 141-142.

Stratigraphic Position:—The Bone Valley gravel rests upon beds of Pliocene or older rocks, and the relation is probably unconformable, but the poor exposures make it impossible to observe contacts except in a few localities. For this reason it may not be safe to postulate an unconformity between the Bone Valley gravel and the underlying Pliocene marls, though the contact with the post-Pliocene beds is certainly .unconformable. The overlying Pleistocene sands rest upon an eroded surface of the Bone Valley gravel, and while the surface of the Pliocene beds does not appear to be very irregular, the widespread character of the unconformity indicates that the interval between the deposition of the Pliocene and Pleistocene was marked by extensive erosion. While the exact correlation of the Bone Valley gravel is somewhat uncertain, it is believed to be younger than the "Arcadia marl," and older than the upper beds of the Caloosahatchee marl. It is probably in part contemporaneous with the Alachua clay. This is inferred from the fact that the two formations were deposited under similar physiographic conditions.

Lithologic Character:—The Bone Valley gravel consists of a fine-grained matrix containing pebbles of phosphate or chert, fragments of bone and other organic remains. The matrix is commonly a marly clay, though sand is not uncommon, especially in the upper part of the formation. The finer grained material is soft and plastic when wet, but upon exposure to the air, hardens to a firm mass. The teeth and dermal plates of sharks and fish are so common in this formation that they may be gathered by the score from the washed material at the phosphate mines.

Thickness:—The Bone Valley gravel is exposed in the land-pebble phosphate mines, but the excavations seldom extend far below the permanent ground water level and the base of the formation is not often reached. The exposures frequently reach a depth of more than thirty feet, without encountering the underlying beds, and hence the maximum thickness may be safely fixed at more than thirty feet. The average thickness, however, is probably lower and it may not exceed fifteen to twenty feet.

Physiographic Expression:—The Bone Valley gravel occupies a region of low altitude and the surface presents only slight inequalities. The formation has been eroded by some of the larger streams which have eroded shallow valleys; and it sometimes forms low hills and ridges. As in the case of the other Pliocene formations, the minor inequalities of the surface are masked by the younger beds of Pleistocene age.

Paleontologic Characters: — The Bone Valley gravel contains abundant organic remains such as fish and shark teeth and worn shells. However, it is probable that these fossils were derived from older geological formations from which they were freed by weathering. They are, therefore, to be regarded as contemporaneous with the phosphatic pebbles and older than the gravels in which they are found. The Bone Valley gravel appears to contain practically no fossils which are contemporaneous with the deposition of the beds.

Structure: — While the Bone Valley gravel shows no marked structural features, it appears to have a gentle seaward inclination. From the mode of origin of this formation it is thought that this dip may be original and not the result of tilting subsequent to deposition. If the formation has been folded, the deformation is so slight that it does not show in the limited exposures which may be observed in the pebble phosphate mines. However, it is not improbable that gentle arching such as may be seen on the Caloosahatchee River also exists in the pebble-phosphate region.

Local Details:—Partial sections of the Bone Valley gravel may be observed in most of the land-pebble phosphate mines. These sections have certain general characteristics which are worth noting. First, there is a deposit of a few inches to several feet of light gray to white sand or coarse sandy loam which rests unconformably upon the Pliocene beds. The Pliocene beds may be roughly divided between the non-productive marls and gravels; and those which are commercially valuable, on account of the high percentage of phosphatic pebbles which they contain. The miners group the Pleistocene and the non-productive Bone Valley beds under the term "overburden," because they must be removed in order to reach the productive beds. The occurrence in the Bone Valley gravel of many sharks' teeth and fragments of bones and shells may readily be explained by the fact that they could have been derived by weathering and erosion from a pre-existing formation. This view receives some confirmation from the fact that many of the fragments are rounded and they are associated with water-worn pebbles which appear to have been given their present form as the result of erosion and transportation. As the percentage of phosphate diminishes toward the top of the gravels, the organic remains become less numerous. This

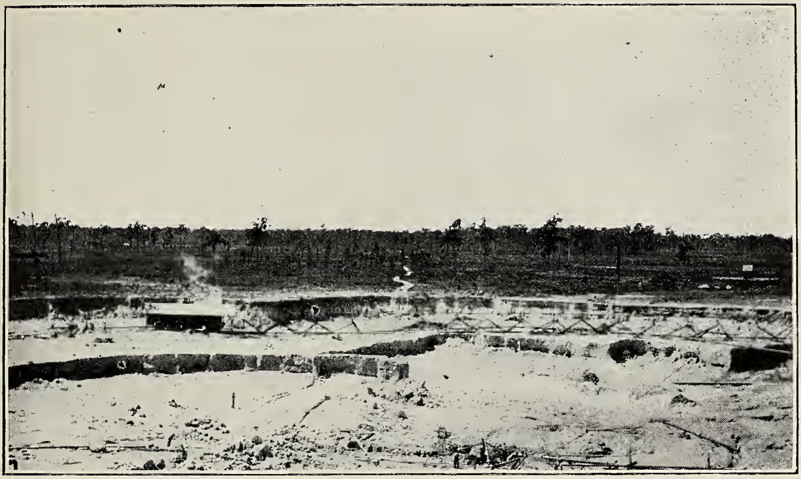


Photo by Sellards.

FIG. 1. — LAND PEBBLE PHOSPHATE, SHOWING BEDDED DEPOSIT, BARTOW, FLA.

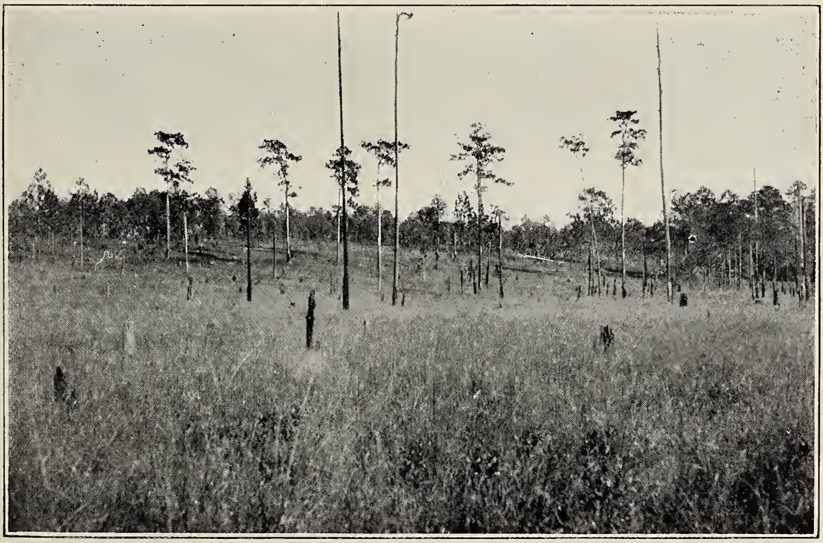


Photo by L. W. Stephenson.

FIG. 2.—PLEISTOCENE TERRACE AND ESCARPMENT BORDERING ST. MARYS RIVER ON FLORIDA SIDE OF RIVER, OPPOSITE TRADERS HILL, GA.

probably means that the deposition of the upper part of the gravels took place when the land was rising rapidly enough to rejuvenate the streams and thus permit them to carry materials from some distance inland, beyond the belt of rocks which supplied the phosphatic pebbles.

PLIOCENE?

LAFAYETTE FORMATION.

The Lafayette formation occupies a large area in the Coastal Plain and has been discussed by a number of authors. The most comprehensive report dealing with this formation is that of McGee[1], published in the Twelfth Annual Report of the United States Geological Survey. The name is derived from Lafayette[2] County, Mississippi, where the formation is well developed. The name Lafayette formation is synonymous with "Orange sand" and "Appomattox formation." However, it is probable that each of these names may, at times, have been used to include beds of various geological ages, and hence the exact significance of the terms have varied with localities, and even in a single locality various writers may have used the names with a different significance.

The Lafayette formation, as the term is used in this discussion, is the equivalent of the Lafayette of Smith,[3] and it is doubtless the equivalent of the upper part of the Altamaha grit of Veatch.[4]

Stratigraphic Position:—The Lafayette formation rests unconformably upon the Alum Bluff and older formations. The amount of time represented by the unconformity at the base of this formation is difficult to determine. The surface upon which the Lafayette was deposited appears to have been comparatively even; but this may either mean that it had not been extensively eroded after the deposition of the older formations; or that it had been worn down to a nearly uniform altitude. The Lafayette formation is unconformably overlain by the white sand of Pleistocene age, and in this case the extensive erosion which occurred between the deposition of the two formations indicates the lapse of considerable time during which there were marked changes in the altitude and surface configuration of the land.

---

[1] McGee, W. J., U. S. Geol. Sur., 12th Ann. Rept., 1890-91, pt. 1, pp. 347-521, 1892.

[2] Hilgard, E. W., Orange Sand, Lagrange and Appomattox, Am. Geol., vol. vii, 1891, pp. 129-131.

[3] Smith, Eugene Allen. The Underground Water Resources of Alabama, Geol. Surv. of Alabama, 1907, pp. 24-25.

[4] Veatch, Otto. Altamaha formation of the Coastal Plain of Georgia. Science, N. S., vol. xxvii, No. 680, 1908, pp. 71-74.

Since there are no organic remains which might serve to correlate these beds with others, it is necessary to resort to some different means to determine their age. If it were possible to trace physical continuity between them and their fossiliferous marine equivalents, their age could be determined by means of the organic remains found in the latter; but thus far this method has been unsuccessful. However, there still remains a possibility of correlation by stratigraphic and physiographic methods. In discussing the geologic and physiographic history of the State, an attempt will be made to show that the Lafayette formation was deposited under conditions which prevailed during the deposition of neighboring marine and non-marine Pliocene, and that the subsequent history of these two series of deposits has been essentially the same. The conclusion from this line of evidence is that the Lafayette is probably of Pliocene age, though it is possible that there has been included with it beds of similar lithological character which are older than the Pliocene.

Lithologic Characters:—The materials composing the Lafayette formation vary from clay and fine sand to coarse sand containing small pebbles, the whole being commonly stained with enough oxide of iron to give the deposit a deep orange color. These sands and clays are the insoluble residue of mature weathering, which probably took place under physiographic conditions which favored the accumulation of the material *in situ*. Such conditions would be furnished by a surface of slight relief and low altitude. A subsequent increase in altitude would rejuvenate the streams and permit them to remove these residual products and redeposit them in their present situation. The variation in physical character, together with the lenticular character of many of the beds and numerous instances of cross bedding show the changing conditions under which the Lafayette was deposited. The physical character of the sediments, together with the absence of marine shells and the sporadic occurrence of fresh water fossils suggests that the beds were either fluviatile or estuarine rather than marine, though the fact that in Florida they rise to a nearly uniform altitude may be regarded by some geologists as an argument in favor of a marine origin. However, the question of the origin of the Lafayette formation is one of the disputed points in North American geology. Those who are familiar with the non-marine deposits of the Great Plains and other similar regions are inclined, for the most part, to regard the Lafayette as non-marine; while those who have investigated the terraces of the Atlantic Coast are usually ardent advocates of the hypothesis of marine origin.

The solution of this problem calls for both stratigraphic and physiographic study of a much larger field than any single State and the results obtained from the recent studies in Florida do not shed new light upon the question. For this reason, the matter should be left for subsequent investigation.

Thickness:—Though widely distributed, the Lafayette formation is comparatively thin, seldom exceeding 30-60 feet, and having perhaps an average thickness of less than 50 feet.

Physiographic Expression:—The Lafayette has undergone extensive erosion since its deposition, and so much of the original material has been re-worked and re-deposited under varying conditions and in different physiographic positions that it is now difficult to determine which deposits were original and which are to be classed as the secondary products from the erosion of the original. However, considered from a broad physiographic standpoint, there are a series of more or less flat-topped hills and dissected table lands, in the northern part of the State, which can best be explained as remnants of a more extensive deposit which was formed when the region was one of low relief. It is difficult to make any close correlation between the separate remnants of this upland because the amount of erosion which they have suffered since deposition has varied greatly, and, furthermore, if the formation is non-marine, close accordance in altitude is not to be expected, because the surface of such a deposit would probably not be even, but would vary slightly from place to place. The general range in altitude for this tableland is approximately 50 feet, and there is a gradual increase from about 250 feet above sea level at the southern margin of the upland to nearly 300 feet above the same datum plane along the northern boundary of the State.

Paleontologic Characters:—The Lafayette formation is not known to contain fossils of marine organisms, except such as have been derived from the erosion of older strata. Remains of land and fresh water fossils have been found outside the state; but no fossils of any sort have been reported from this formation in Florida, and since the beds are well exposed, it appears safe to say that it does not contain many.

Structure:—The Lafayette formation shows no structural features of interest, though it may have been subjected to the same deformation which produced the gentle arching of the marine Pliocene beds.

Local Details:—The Lafayette formation occupies a belt about 40 miles in width, extending from near the Suwanee River westward to Escambia County. Some large tracts are found in Gadsden, Leon and Jefferson Counties on the east side of the Apalachicola River; and in Holmes, Walton, Santa Rosa and Escambia Counties in West Florida. This formation is typically developed in the upland of the counties along the north line of the State, but good exposures are rare. The red sands of the counties mentioned are largely assigned to the Lafayette formation, though the accuracy of this correlation is sometimes doubtful, because of the absence of fossils. The selection of typical sections of the

Lafayette formation is a difficult task because of the uncertainty which frequently attends the identification and correlation of exposures of the formation. While the number of sections given below is limited, they are believed to be fairly representative of the formation as it is developed in Florida. Some sands belonging to this formation have already been mentioned in connection with the sections of other formations.

In the descriptions of sections made by Vaughan[1] in the vicinity of Tallahassee, the red sands are thought to represent the Lafayette formation, though there is a probability that they are in part weathered portions of Oligocene beds.

Section on the St. Augustine road from Hancock's place to the Seaboard Air Line Railway, south side of railway.

Red sandy clay (from plateau summit)	55 feet.
Interlaminated gray clays and sands and gray clays (level of railroad)	16 feet.
Contact of sands and clays shelves downward toward north, descending through 16 feet. The contact of sands and clays dips at a less angle than the clay for a stretch of 20 feet.	
In ravines, southern edge of Tallahassee, north of Seaboard Air Line Railway.	
Red sands to the top of the head of the gulch.	
Clay	35 feet.
Gray grit, at	10 feet.
Gray clay (apparently very siliceous), at	5 feet.
Blanket of gritty sand. Base of bluff	0-5 feet.

The base of this section is probably 20 feet above the clay in the previous section.

Section on Bellair Road, south from Tallahassee, south side Seaboard Air Line Railway.

Soil, sand, etc.	1 foot.
Massive, plastic gray blue clay, cuboidal fracture	10 feet.
Sands and siliceous clay (of the appearance of the Alum Bluff)	3+feet.

By aneroid, the base of this section is sixty feet below the capital terrace and thirty feet above the railroad crossing.

Vaughan's comment is that "the clays at this locality are lower than in Tallahassee and higher than on the St. Augustine road, i. e., the contact between the red sands and the underlying clays is an uneven surface." The actual relations between the sands and clays were difficult to observe, but the indications from aneroid observations are that the sand rests on an uneven, probably eroded surface:"

Section at McCullough's Bridge, ten and a half miles northwest of De Funiak Springs,[2] just below mill pond.

---

[1] Vaughan, T. Wayland. Unpublished notes.

[2] Vaughan, T. Wayland. Unpublished notes.

3.	Light yellowish gray sands, est.	3 feet.
2.	Red gritty sands and small pebbles, somewhat argillaceous, with clay seam, ½ to 2 inches thick, cross bedded on a large scale near the base, resting unconformably on, est.	10 feet.
1.	Yellow argillaceous sands interlaminated with gray clay	6½ feet.

2. Lafayette.

I was informed by a local resident that this outcrop is on Sec. 2, T. 4, R. 20.

On Rock Hill south of Chipley, there is an exposure, of which the upper member probably represents the Lafayette. The age of the lower part of the outcrop could not be determined. The section at this locality is given below.

Red sand and gravel, containing pebbles up to 1 inch in diameter. In places cemented into hard conglomeratic boulders several feet in diameter	20 feet.
Hard yellowish gray to green sandstone with pebbles of soft green clay	10 feet.

Sections of Lafayette were observed on the tops of hills about 250 feet above tide on the road between River Junction and Aspalaga Bluff. A short distance from River Junction the following section was leveled:

Red sand, containing numerous pebbles	8-10 feet.
Red argillaceous sand	45 feet.
Gray marly clay, strained with iron oxide	1+feet.

About five miles from River Junction, another similar exposure was observed. The section at this locality is as follows:

Friable orange sandstone, containing some lenses of clay and some pebbles	15 feet.
Gray sandstone, streaked with yellow iron stains, well cemented	5 feet.

QUATERNARY.

The Quaternary is commonly divided into Pleistocene and Recent, but a difficulty often arises in attempting to discriminate Pleistocene and Recent, for the reason that the name Pleistocene is associated with the glacial period and Recent with the time since the final melting of the great sheets of ice which covered large areas of the northern parts of Europe and North America. In regions like Florida, remote from the direct influence of glaciation, it is always difficult, and frequently impossible, to draw satisfactory lines between the deposits of the two periods. In this discussion the term Quaternary will be applied to deposits which may belong to either Pleistocene or Recent or to both. The name Pleistocene will, as far as possible, be restricted to such beds as may safely be placed in the early part of the Quaternary, and are probably to be correlated chronologically with the glacial deposits farther north. The name Recent will be restricted to deposits which are clearly of late geologic age, such as sand dunes, alluvial sands, etc. In general, it is considered safe to draw the line between the two periods at the final emergence of the low lands from beneath the sea; and, as this movement appears to be the most marked physical change since the early Quaternary, it probably forms the best line of demarcation between Pleistocene and Recent. While theoretically the line may be drawn with considerable exactness, the discrimination of Pleistocene and Recent deposits often presents many practical difficulties because the changes in conditions governing deposition were gradual and the materials for the Recent deposits were often derived directly from the beds of late Pleistocene age.

PLEISTOCENE.

In Florida, the beds of Pleistocene age include both marine and non-marine deposits, and the non-marine beds may be separated, on the basis of origin, into residual, lacustrine, fluviatile and aeolian.

FOSSILIFEROUS MARLS.

General:—The fossiliferous marine Pleistocene appears to be one of the oldest Quaternary formations. It comprises a series of sands and shell marls with a sandy matrix. From a deposit of fossiliferous sand on North Creek, a tributary of Little Sarasota Bay, Dall[1] describes a large number of fossils. The shell bed according to this writer consists of sand, darkened by organic matter, and the total thickness is less than two feet.

During the progress of the field work for this report collections were obtained which indicate that the fossiliferous Pleistocene is much more extensively developed than was formerly believed. The beds containing fossils of this age present a great uniformity in character, being composed of white or light gray sands, usually coarse-grained and sometimes containing layers of marine or fresh water shells. Rarely beds of clay occur interstratified with the sand, and sometimes the material contains scattered argillaceous material. The fossils are usually found near the base of the beds and the fauna sometimes changes from marine near the base of the exposures to non-marine above, indicating a freshening of the water. In many localities the fossils are confined to the lower layers of sand. In such cases, the absence of fossils in the upper part of the sand may have been caused by partial emergence of the beds during deposition. Sharks' teeth, pieces of bone, and other organic remains are common in the basal portion of these sands at many localities, and their source was probably the underlying formations. A rare but interesting example of such a conglomerate was found by Stephenson[1] at Stokes Ferry, on the St. Marys River. The materials comprised a shark's tooth, a fragment of a mammoth's tooth, ear bones of a whale, a fragment of a plate from the shell of a turtle, three horses' teeth and indeterminate bone fragments. Pebble phosphates are also common in the basal portion of the sands of Pleistocene age. Some unsuccessful attempts have been made to mine them, but the deposits have usually been found too thin to be of economic value. Examples of phosphates of this character are to be found at many localities in the peninsula. They represent the hard materials separated from the residual clays and sands by the action of the waves and currents in the Pleistocene sea. The absence of extensive clay beds in the sands of Pleistocene age is due to its scarcity in the older geologic formations from which the sands were largely derived. This characteristic of the geological formations of Florida is so pronounced that good clays are comparatively rare, except in certain localities of limited area.

---

[1] Dall, Wm. H., Wagner Free Inst. Sci., Trans., vol. iii, pt. 6, 1903, pp. 1615-1616.

The fossiliferous marine beds of Pleistocene age are probably more widely distributed in Florida than in any other State east of the Appalachian Mountains. Collections of Pleistocene fossils were obtained from the marls at Labelle, Sarasota Bay, Manatee and Six-Mile Creek near Tampa, on the west coast; and at Ft. Lauderdale, Eau Gallie, Titusville, and Mims on the east coast. In the center of the peninsula no exposures of the marls were found; but samples obtained by Dr. Sellards at a depth of 100 feet from the well of Capt. H. Clay Johnson, at Kissimmee, show that the marine marls of Pleistocene age occur at that locality, beneath nearly 100 feet of sand. This suggests that they probably extend some distance north of Kissimmee in the east-central portion of the peninsula. The distribution of the exposures of the marls over such a wide area in a region where the beds are practically horizontal and undissected, as is the case in the southern part of the peninsula, indicates that a very large area is probably underlain by them. Thus they doubtless extend along the western coast from Tampa southward to near Fort Myers. From near Labelle the inner margin swings northward, passing east of Arcadia and Bartow to some distance north of Kissimmee, and then turns eastward. On the east side of the peninsula the marls of Pleistocene age extend north to Orange City and Mims, and they may extend through the low valley occupied by the St. Johns River. Throughout the area where these beds are known they maintain striking similarity of texture, indicating widespread uniformity of conditions governing deposition.

---

[1] Stephenson, L. W. Unpublished notes.

Local Details:—In general, the Quaternary formations of the northern part of the State, and as far south as Lake Okeechobee present very little variation, and hence, the discussion of local details is omitted except in the case of the shell marls. A section of the Pleistocene shell marl at Orient station, where it rests unconformably on the Tampa formation, shows:

White sand	2 feet.
White sandy marl	6 feet.
Light gray sand	1 foot.
Gray shell marl	0-1 foot.
Total	7-8 feet.

The lower member of the above section furnished the fossils listed below:[1]

Locality:—Six-Mile Creek, Orient, Hillsboro Bay, ¼ mile + below R. R. bridge.

Marginella apicina Menke.
Olivella mutica Say.
Fasciolaria distans Lam.
Fulgur perversum Linn.
Fulgur pyrum Dillwyn.
Melongena corona Gmel.
Tritonidea cancellata Conrad.
Nassa vibex Say.
Muricidea floridana Conrad.
Urosalpinx perrugatus Conrad.
Neverita duplicata Say.
Crepidula convexa Say.
Arca transversa Say.
Ostrea young, *virginica* Gmel.
Pecten gibbus Linn.
Carditamera arata Conrad.
Phacoides anodonta Say.
Phacoides multilineatus T. and H.
Cardium isocardia Linn.
Laevicardium mortoni Conrad.
Callocardia sayana Conrad.
Transennella caloosana Dall.
Macrocallista nimbosa Sol.
Venus campechiensis Gmel.
Chione cancellata Linn.
Anomalcocardia caloosana Dall.
Tagelus divisus Spengl.
Semele purpurascens Gmel.
Spisula similis Say.
Mulinia lateralis Say.
Corbula cuneata Say.

Geologic horizon:—Pleistocene.

In a ditch about ⅛ mile south of Manatee Station, there is an exposure of sandy marl which contains an abundance of fossils. The species[2] collected at this locality are given below.

Locality:—Ditch, side of railroad, ⅛ mile south of Manatee Station, 2 to 4 feet from the surface.

Bulla striata Brug.
Tornatina canaliculata Say.
Terebra protexta Conrad.
Terebra dislocata Say.
Olivella mutica Say.
Volutella ovuliformis Orb.
Marginella apicina Menke.
Fulgur perversum Linn.

---

[1] Identifications by Dr. Vaughan.

[2] Identifications by Dr. Vaughan.

Fulgur pyrum Dillwyn.
Fasciolaria gigantea Kiener
Fasciolaria apicina Dall.
Nassa vibex Say.
Muricidea floridana Conrad.
Astyris lunata Say
Pyramidella.
Syrnola.
Turbonilla.
Turbonilla.
Niso.
Bittium varium Pfr.
Cerithium muscarum Say.
Crepidula plana Say.
Crepidula convexa Say.
Arca transversa Say.
Mytilus exustus Linn.
Modularia lateralis Say.
Phacoides multilineata T. and H.,
Phacoides anodonta Say.
Lucina.
Montacuta floridana Dall.
Montacuta.
Cardium robustum Sol.
Cardium isocardia Linn.
Laevicardium serratum Linn
Chione cancellata Linn.
Callocardia.
Transennella caloosana Dall.
Anomalocardia caloosana Dall.
Parastarte triquetra Conrad.
Tellina.
Angulus declivis Conrad.
Angulus.
Macoma.

Geologic Horizon:—Pleistocene.

One-fourth mile south of the railroad station at Orange City there is an exposure of marl which is doubtfully referred to the Pleistocene though further collections may show it to be Pliocene.

The section at this locality has a thickness of about 18 feet, but only the lower part is fossiliferous:

Unassorted white sand	3 feet.
Stratified hard white sandy clay	3 feet.
Well stratified ferruginous sand and clay	5 feet.
Yellow to white marl, very fossiliferous	7 feet.
Total	18 feet.

The basal member of this section furnished the fossils listed below:

Locality:—One quarter of a mile south of the railroad station, Orange City, Florida.[1]

Melampus lineatus Say.
Terebra concava Say.
Olivella mutica Say.
Oliva literata Lam.
Fulgur pyriformis Conrad
Littorina irrorata Say.
Leda acuta Conrad.
Arca transversa Say.

Locality:—Well at Kissimmee, Florida; depth, 96 feet from surface.

Olivella sp.
Certithium muscarum Say.
Crepidula fornicata Say.
Fissuridea alternata Say.
Glycymeris pectinata Gmel.
Arca penderosa Say.
Arca transversa Say.
Ostrea equestris Say.

---

[1] Identifications by Dr. Vaughan.

Pecten gibbus Linn.
Anomia simplex Orb.
Mytilus exustus Linn.
Crassinella lunulata Conrad.
Venericardia tridentata Say.
Carditamera arata Conrad.
Phacoides trisulcatus Con.? Young
Phacoides linteus Conrad.
Phacoides nassulus Conrad.
Phacoides multilineatus T. and H.
Chama arcinella Linn.
Cardium isocardia Linn.? worn.
Callocardia sayana Conrad.
Transennella caloosana Dall.
Macrocallista nimbosa Sol.
Chione cancellata Linn.
Venus campechiensis Gmel.? worn young.
Timoclea grus T. and H.
Anomalocardia brasiliana Gmel.
Abra aequalis Say.
Donax variabilis Say.
Spisula similis Say.
Mulinia lateralis Say.

Geologic horizon:—Pleistocene.

From another well at Kissimmee Dr. Vaughan identified the fossils listed below. It is interesting to note the fact that the sample came from about the same depth as the one mentioned above.

Ostrea virginica Gmel.
Crassinella lunulata Conrad.
Crassinella sp.
Carditamera arata Conrad.
Venericardia tridentata Conrad.
Venericardia perplana Conrad.
Phacoides multilineatus T. and H.
Phacoides amiantus Dall.
Venus campechiensis Gmel.
Callocardia sayana Conrad. Upper Olig. to Pleistocene.
Parastarta trigona Dall. Miocene and Pliocene.
Spisula subparilis Conrad.
Mulinia lateralis Say.
Corbula inaequalis Say. Miocene-Pliocene.

Geologic horizon:—Probably Pleistocene, but may be Pliocene.

From near the bottom of the 100-foot well of Capt. H. Clay Johnson at Kissimmee, the following fossils were obtained:

Arca transversa Say.
Carditamera arata Conrad.
Chione cancellata Linn.

The above list suggests that the material at a depth of 100 feet is Pleistocene.

From a decomposed coquina 1 mile north of Mims, Dr. Vaughan identified *Glycymeris pectinatus* Gmel., and *Donax variabilis* Say. The age of this deposit is doubtless Pleistocene. It is covered by white Pleistocene sand, beneath which it rises in the form of a long ridge, which may represent an old beach.

A loosely cemented sandy shell marl one mile west of Titusville furnished several identifiable shells mixed with many worn fragments. The species[1] which were identified are Pleistocene:

Locality:—One-quarter of a mile north of Mims, Florida.

---

[1] Identifications by Dr. Vaughan.

Glycymeris pectinatus Gmel.
Donax variabilis Say. forming coquina.

Geologic horizon:—Pleistocene.

In a ditch 4 miles west of Eau Gallie, there is a good exposure of sandy shell marl covered by from 1 to 3 feet of white Pleistocene sand.

Locality:—Four miles west of Eau Gallie, Florida.

Astrangia solitaria LeS.
Pleurotoma (Drillia) thea Dall.
Marginella limatula Conrad.
Marginella apicina Menke.
Olivella mutica Say.
Oliva literata Lam.
Fasciolaria distans Lam.
Fasciolaria gigantea Kiener.
Fulgur perversum Linn.
Fulgur pyrum Dillwyn.
Fulgur maximum Conrad.
Nassa acuta Say.
Nassa vibex Say.
Eupleura.
Astyris lunata Say.
Cerithium muscarum Say.
Bittium varium Pfr.
Crepidula fornicata Say.
Crepidula convexa Say.
Nucula proxima Say.
Arca limula var. *platyura* Dall.
Arca transversa Say.
Crassinella acuta Dall.
Venericardia tridentata Say.
Carditamera arata Conrad.
Phacoides nassulus Conrad.
Phacoides multilineatus Conrad.
Phacoides.
Cardium robustum Sol.
Cardium isocardia Linn.
Laevicardium mortoni Conrad.
Venus campechiensis Gmel.
Venus tridaconides var. *rileyi* Conrad.
Transennella caloosana Dall.
Chione cancellata Linn.
Timoclea grus T. and H.
Anomalocardia caloosana Dall.
Petricola pholadiformis Lam.
Tellina (Angulus) declivis Conrad.
Tagelus divisus Spengl.
Donax variabilis Say.
Semele cancellata d'Orb.
Mulinia lateralis Say.
Corbula barrattiana C. B. Ads.
Corbula caloosana Dall.

Two miles southwest of Eau Gallie on Merritts Island there is a section which shows about 8 feet of coquina covered by 2-4 feet of white Pleistocene sand. The lower part of the sand supplied the fossils[1] in the accompanying list.

Locality:—Two miles southeast of Eau Gallie, on peninsula south of point of Merritts Island, Florida.

Fulgur pyrum Dillwyn.
Fulgur maximum Conrad.
Melongena corona Gmel.
Crepidula fornicata Say.
Arca ponderosa Say.
Arca transversa Say.
Cardium robustum Sol.
Chione cancellata Linn.
Venus campechiensis var. *tetrica* Conrad.
Donax variabilis Say.
Mulinia lateralis Say.

Geologic horizon:—Pleistocene.

Well records in various parts of the State show the presence of the Pleistocene beds, but only in the cases where samples have been preserved has it been possible to recognize with certainty the shell marls of that age.

---

[1] Identifications by Dr. Vaughan.

In the well at Ormond Hotel, Ormond, a hard sandy marl was encountered between 50 and 56 feet from the surface. From a sample of this rock, Dr. Vaughan identified *Donax variabilis* Say, etc. Between 66 and 68 feet, a gray sandy marl was encountered which furnished *Littorina irrorata* Say, *Arca pexata* Say and *Mulinia lateralis* Say. Dr. Vaughan regarded these samples as Pleistocene. At a depth of 66 to 90 feet, the material was still a marl but unfortunately the organic remains were too meager to determine whether the material was Pleistocene or Pliocene.

The well of the Model Land and Railroad Company at West Palm Beach may be entirely Pleistocene, but fossils were only identified from samples No. 4 and No. 5. Sample No. 4 at a depth of 55-70 feet furnished *Crepidula fornicata* Say, *Pecten gibbus* Linn., *Cardium robustum* Sol., and *Venus mortoni* Conrad, which were thought to be Pleistocene and this conclusion was strengthened by the occurrence of *Donax variabilis* Say in sample No. 5, which was obtained at a depth of 70-74 feet. In another well at the same locality, the Pleistocene marls were identified in samples extending from 8 to 57 feet.

Gray Sand:—One of the most widespread formations of the Atlantic and Gulf coastal plain is a white or light gray coarse grained sand. Locally, some of the subsurface layers of this sand have been stained light yellow or even red by a deposit of iron oxide, but the colors when present are usually less prominent than those of the Lafayette formation. This material, which has commonly been called white sand, covers nearly all of Florida and rests unconformably upon the older geological formations. It forms the surface over all the lowlands; and much of the elevated region toward the northern end of the State. In the valleys the white sand forms a mantle over a large part of the slopes where it is arranged in more or less well defined terraces. Locally, the sand has been removed from hillsides by erosion.

Lithologically this sand presents no marked peculiarities. It is everywhere coarse and is on the whole remarkably free from silt or clay. The sand grains are not materially different, in form, from those of the present beach. The quartz grains belong to the type commonly known as "sharp" sand, being sub-angular to sub-rotund. In this they differ from sands which have undergone extensive wind transportation and have been well rounded by violent impact with other sand grains when not buoyed up by liquid. There is a general absence of clay beds and the sands are apparently non-fossiliferous except near the base of the sections, which extend down nearly to or below sea level where they merge with the fossiliferous marls previously described.

The gray sands are usually uncemented but locally the presence of iron oxide has transformed them to a dense concretionary sandstone which is almost as resistant as quartzite. Examples of rock of this kind are to be seen at several localities along the Louisville and Nashville Railroad north of Pensacola, and at various other places in the State.

While sinking a well at Apalachicola the driller reported a pine log at a depth of 60 feet imbedded in incoherent sands which are probably of Pleistocene age. Other examples of vegetable matter as well as logs have been noted at various localities in Florida. This suggests that swamps may have existed during the deposition of the sands, but the absence of any considerable bodies of peat imbedded in the deposits shows that the marsh conditions were of short duration; or, that the supply of sediment was sufficient to prevent the accumulation of thick layers of pure organic matter. Except near the coast, the thickness of the sands is seldom sufficiently great to mask the topography of the underlying formations and they rarely form any conspicuous topographic features aside from the terraces and a few dunes and low ridges.

Planorbis Rock:—Following the deposition of the main body of the gray sands, there appears to have been a number of shallow bodies of fresh water occupying the depressions in the surface of the newly-emerged sands. In these bodies of fresh water, there accumulated thin deposits of marl which differ from the earlier marls of this period in being composed of calcareous matter nearly free from sand.

In this marl, the most conspicuous fossils are gastropods, especially those belonging to the genus *Planorbis.* While this rock may be in part post-Pleistocene, satisfactory subdivisions can not be established at the present time. This rock should not be confounded with the "*Planorbis* rock" of the Caloosahatchee River, which has been regarded as Pliocene. The "*Planorbis* marls" of Quaternary age have been observed at Daytona, Sanford, and on the Santa Fe River, southwest of Fort White; and, according to Eldridge,[1] they occur in most of the "hammocks" between Kissimmee and Lake Okeechobee.

The Quaternary deposits of the southern end of the peninsula and the keys will be discussed in a subsequent chapter by Mr. Samuel Sanford; and, hence, they will be omitted from the general discussions of the Pleistocene and Recent beds.

Coquina:—One of the most common of the marine Quaternary deposits is the coquina which occurs at various points along the coast.

---

[1] Eldridge, Geo. H. Unpublished notes.

This consists of a mass of more or less water worn shells cemented by calcium carbonate. The amount of cement is seldom great enough to close the openings between the individual shells, though in some localities the process of cementation has proceeded far enough to produce a rather compact fossiliferous limestone. There is usually more or less sand present which is commonly in the form of thin laminæ separating the shell beds, and various gradations from sand rock to shell rock may be noted along the Florida coast. (Pl. VII, Fig. 2.)

This rock was described by several of the earlier writers on the geology of the State. The following account is from a paper published by Jas. Pierce in 1825.[1]

> Extensive beds of shell rock, of a peculiar character, occupy the borders of the ocean, in various places from the river St. Johns to Cape Florida. They are composed of unmineralized marine shells, of species common to our coast, mostly small bivalves, whole and in minute division, connected by calcareous cement. I examined this rock on the isle of Anastasia opposite St. Augustine where it extends for miles, rising twenty feet above the sea and of unknown depth. It has been penetrated about thirty feet. In these quarries, horizontal strata of shell rock of sufficient thickness and solidity for good building stone, alternate with narrow parallel beds of larger and mostly unbroken shells, but slightly connected. Hatchets are used in squaring the stone. Lime is made from this material, of a quality inferior to ordinary stone lime.
>
> The large Spanish fort,[2] and most of the public and private buildings of St. Augustine, are constructed of this stone. The rock extends in places into the sea, with superincumbent beds of new shells of the same character.
>
> Similar shell rock is found on the continent in several places.

Of the organic Quaternary rocks Dall says:

> There is general opinion among the inhabitants, which was frequently expressed to me, in conversation, to the effect that between Tampa and the Keys, coquina-rock is only to be found at one place, the mouth of Little Sarasota Pass. But this idea is certainly erroneous, as at every projecting point of the Keys along the Gulf shore which we visited, I found traces of this rock, though often not visible above water, and frequently composed more of sand-grains than of shell, so that it looks much like wet loaf sugar.[3]

"Vermetus Rock":—Another organic rock which has been described by Dall[4] is now being formed by colonies of a small gastropod *Vermetus* (*Petaloconchus*) *negricans*. This organism secretes a skeleton in the form of a winding calcareous tube and when the tubes

---

[1] Pierce, James, Am. Jour. Sci., 1st ser., vol. ix, 1825, p. 123.

[2] The fort referred to is the one now known as Fort Marion.

[3] Dall, Wm. H., Geology of Florida, Amer. Jour. Sci., vol. xxxiv, 1887, pp. 162-163.

[4] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey Bull. 84, 1892, p. 153.

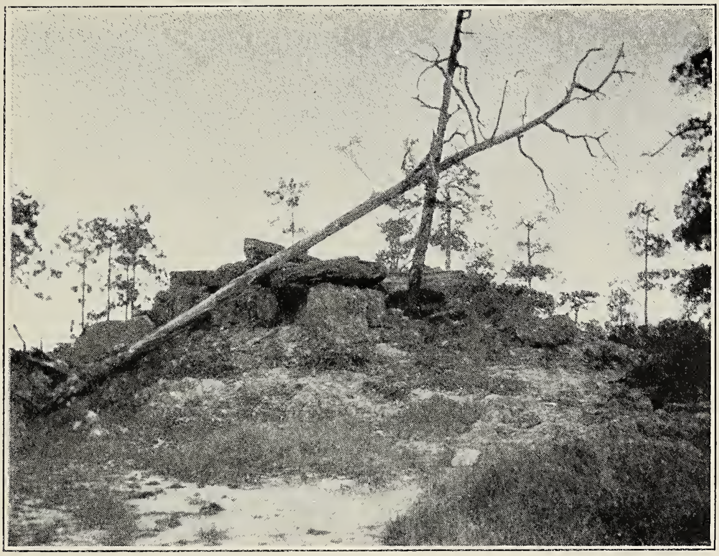


FIG. 1.—CONGLOMERATE OF LAFAYETTE FORMATION RESTING ON SANDSTONE OF UNCERTAIN AGE, TOP OF ROCK HILL, WASHINGTON COUNTY, FLORIDA.

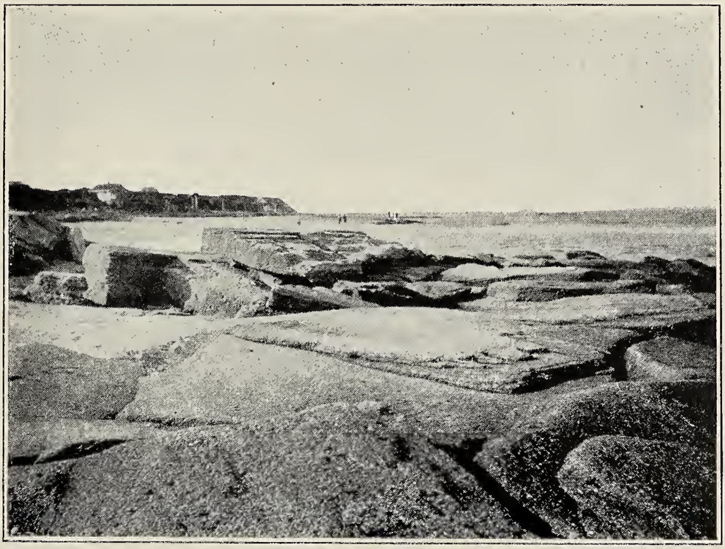


FIG. 2.—OUTCROP OF COQUINA ROCK NEAR LIGHTHOUSE, ANASTASIA ISLAND, OPPOSITE ST. AUGUSTINE, FLA.

of a colony are seen united together they are thought to resemble coral, hence the local name "worm coral." This rock is now being formed on the coast, and it doubtless extends back to the Pleistocene and possibly even to the Pliocene for Dall[1] reports the same species of gastropod from the Caloosahatchee marl.

Yellow Sand:—With the Pleistocene is included a silty or clayey yellow sand which is widely distributed on the highlands in the central part of the peninsula. This material which is evidently the residual product left by the solution of the underlying rock is found on all the Oligocene formations and it probably began accumulating immediately after the final emergence of these beds from beneath the sea. However, much of the residual products of these rocks has doubtless been removed since the beginning of its formation and what remains mostly represents the results of weathering since the depression which resulted in the deposition of the marine Pliocene beds, but probably a portion of the deposit was formed during the preceding epochs. For convenience, it is all included under the Pleistocene. It was this material which Dall[2] described under the head of yellow sand, and from the analysis which he gives, the deposit appears to be about eighty per cent silica. Lime, which was presumably the most abundant constituent of the original rock, has dwindled to less than two per cent, but this condition is to be expected since the residuum of the weathering of limestone is the insoluble silica and silicates which existed as impurities in the original rock.

Stratigraphic Position of the Pleistocene:—Where the contact between the gray Pleistocene sands and the older formations has been observed, it is characterized by marked unconformity due to erosion. The relation between the gray and yellow sands has been observed at many localities and it is unconformable. The yellow sand appears to pass by gradation to the underlying Oligocene from which it was derived by weathering. The stratigraphic relation between the Coquina and the "*Vermetus* rock" and the underlying beds has not been observed but it is doubtless unconformable.

With the exception of the yellow residual sand, the relation between the various members of the Pleistocene and the overlying Recent deposits is conformable. In fact, the gradation between the Pleistocene and Recent beds often makes it impossible to differentiate between them. This is the case with the sands of Recent age, which are usually derived from the erosion and redeposition of the sands derived from the beds of Pleistocene age. Frequently the materials have not been transported far, and, in many instances, the lack of definite arrangement of the layers renders the recognition of an unconformity very uncertain. The interpretation of the observations is also subject to considerable unreliability because it is difficult to say whether such unconformities as are seen are general or merely local.

---

[1] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, p. 153.

[2] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, pp. 154-156.

Thickness of the Pleistocene:—In Florida, the beds of Quaternary age vary greatly in thickness; and, in some localities, they are wholly wanting. The variation in thickness is due to uneven deposition on a surface which had been more or less dissected by erosion. The gray sands are commonly not more than 3 or 4 feet thick, but in places they rise in sand dunes 40 or 50 feet high and near the coast they thicken rapidly, hence, their maximum thickness is over 50 feet.

The thickness of the coquina is difficult to determine because sections showing the base are rare and well records are frequently unreliable—the driller often reporting as "coquina" any rock which is soft and contains abundant shell fragments. However, at St. Augustine it is known to attain a thickness of over 30 feet and at various points along the east coast sections from 3 to 10 or 12 feet may be seen.

Where the shell marls are exposed, they seldom attain a thickness of more than 3 or 4 feet; but if we include the non-fossiliferous gray sand immediately overlying them, these figures will usually be increased three or four fold. The data supplied by well samples indicate that the Quaternary along the east coast varies in thickness from about 40 feet at Jacksonville to over 70 feet at West Palm Beach and more than 100 feet at Miami.

Along the west coast the information is much less satisfactory, and it is probable that from the Manatee River northward nearly to Carrabelle the Quaternary is usually less than 30 feet thick though in places it exceeds 50 feet. At Carrabelle the "Sopchoppy limestone" was encountered at about 50 feet, but some of the overlying sands and clays may be older than the Quaternary. Westward in the vicinity of Pensacola, there is a great thickness of sands with some thin clay beds. While it has been impossible to get satisfactory collections of fossils from the wells that penetrate these sands, it appears probable that the Quaternary may attain a thickness of several hundred feet near the coast.

At Kissimmee in the south-central part of the peninsula, the presence of Pleistocene fossils in a well at a depth of 100 feet probably indicates that the beds thicken toward the south. This conclusion has been verified by the work of Mr. Sanford whose report appears in a subsequent chapter.

On the uplands of the peninsula the yellow sand is commonly thicker than the white. It has been penetrated to a depth of over 50 feet in the vicinity of Lakeland, and, at other localities in the south central part of the peninsula it is known to have a thickness of 20 to 30 feet at several localities.

Physiographic Expression of the Pleistocene:—In the coastal belt the Quaternary is characterized by low relief, being a region of low sandy plains crossed by shallow valleys and often covered by broad marshes and ponds which are seldom more than 2 or 3 feet in depth. The Quaternary of the interior is usually characterized by the same topography as the underlying rocks. It commonly forms a thin coating on the hilltops and a broad terrace deposit in the valleys. Locally erosion has removed the Quaternary from the hilltops or slopes, thereby exposing the underlying beds. In some localities, especially along the east coast, wind action has built the sand into dunes and ridges which locally rise to a height of 30 to 50 feet and form conspicuous topographic features.

Paleontologic Characters of the Pleistocene:—The Pleistocene fauna bears a close resemblance to that now living along the coast. This fact is illustrated by the collection from North Creek which, according to Dall,[1] comprised seventy-one species, of which five are believed to be extinct.

Structure of the Pleistocene:—The beds of Pleistocene age show no indications of having been subjected to marked deformation; and their general attitude has probably not been materially changed since their deposition. They appear to have a gentle dip toward the sea and they were apparently raised to their present altitude by a broad movement which was not of such a character as to produce notable flexures in the beds.

RECENT.

The Recent formations of Florida include the alluvial and lacustrine deposits, the recent beach sand and sand rock, coquina rock, and the aeolian sand. The alluvial deposits occur along all the large streams where they form belts from a few yards to a mile or more in width. The alluvium is divisible into the Recent flood plain and terrace deposits of Pleistocene age. During high water, the flood plain is partially overflowed; and, in some localities, the inundated tracts take the form of nearly impenetrable cypress swamps which are flooded during a large part of the year.

Alluvial Deposits:—The Recent silts and sands seldom rise more than a few feet above the high water levels of the streams, and the transition to the terraces above is often poorly defined. The terraces are thought to belong to the Pleistocene and to be associated with a submergence and subsequent emergence during that epoch.

---

[1] Dall, Wm. H., Wag. Free Inst. Sci., Trans., vol. iii, pt. 6, 1903, p. 1616.

Both flood plains and terraces are composed of coarse white sand; or, locally, of yellow and red sands derived from the erosion of the Lafayette formation. Silt and clay are comparatively rare, though, in a few instances the smaller swamps are underlain by these materials. Shells of land and fresh water mollusks occur in the flood plain deposits but they are seldom of importance. The fluviatile deposits of this age often contain more or less gravel, with phosphatic pebbles derived from the erosion of the Bone Valley and other phosphate-bearing formations. It was this material which was formerly dredged from the beds of the streams and was known as *river pebble phosphate.*

Lacustrine Deposits:—The deposits here classed as lacustrine include those now being formed in the numerous lakes and swamps. They consist of white sand derived from the beds of Pleistocene age, and animal and vegetable remains supplied by the growth and decay of aquatic organisms. The sand does not differ greatly from the gray sand of Pleistocene age which covers such a large part of the surface of the State. The organic deposits sometimes form shell marls where they consist of molluscan remains mixed with sand; and, in some localities, where animal remains predominate, they form beds of soft marly limestone. On the bank of the St. Johns River at the mouth of Blue Spring outlet in Volusia County, there is a semi-crystalline limestone, having a thickness of over 4 feet, overlain by 3 feet of sand. The limestone contains many shells of a fresh-water mollusk (Unio) and the sands contain shells of the common land snail (*Helix albilabrum*). From the position of these beds, the sand is evidently of Recent age and the limestone probably belongs to the Pleistocene.

The vegetable remains form beds of peat or muck which frequently reach a considerable depth. They sometimes contain thin beds of sand which were evidently washed into the swamp and there is locally considerable organic silica in the form of tests of diatoms. These deposits which are known as diatomaceous or infusorial earth are sometimes mined and sold for silver polish. Such a mine was formerly operated near Eustis; and, judging from the samples received, the material is of good quality.

"Vermetus Rock":—Under the head of Pleistocene, mention was made of the *"Vermetus* rock" which is formed of the tube-shaped calcareous skeletons of a gastropod. While the formation of this rock probably began in the Pleistocene, its deposition has continued down to the present time, and it forms one of the most interesting of the Recent deposits.

Beach Deposits:—The Recent beach deposits consist largely of sand, though a friable sand rock is not uncommon; and the formation of coquina which began as early as the Pleistocene, has continued down to the present time. The gray sand derived from the Pleistocene deposits is by far the most common material, though locally fragments of rock derived from some of the older geological formations predominate. Such rock has been noted by Heilprin[1] on the Chassahowitzka River, and by Dall[2] at various points along the west coast south of Tampa. An admixture of recent and extinct fossils sometimes results from the erosion and redeposition of the older formations.

Aeolian Deposits:—The aeolian deposits consist of sand in the form of dunes, ridges or more or less irregular hillocks. These occur in many localities from the northern line of the State southward to the vicinity of Lake Okeechobee; but are best developed along the east coast. In the interior, ridges and dunes are seldom conspicuous. This is probably to be ascribed to the topography, vegetation and climatic conditions. During a large part of the year the ground water stands very near the surface, especially where the relief is slight and this serves to keep the sand moist and prevent its being blown about by the wind.

Another factor which hinders the formation of dunes in the interior is the general absence of strong winds blowing from a single direction. This is well shown by contrast with the islands along the east coast where the prevailing winds from the northeast have resulted in the formation of dunes which in places attain a height of over 50 feet as far south as Dade County. And finally, the presence of a luxuriant subtropical vegetation not only protects the sand from the direct force of the wind but also tends to hold it in place by means of a matting of roots and stems.

Chemical Deposits:—In a region where solution is so prominent, chemical deposits would naturally be expected, but aside from the extreme southern end of the State such deposits do not appear to be important. The chemical deposits are of two classes, one being formed from underground water where it emerges in the form of springs, and the other being deposited in crevices and caverns beneath the surface. The spring deposits vary with the character of the material carried in solution. The waters containing hydrogen sulphide deposit sulphur which appears as a white flocculent material coating the plants and earth at the point of emergence. Other waters deposit carbonate of lime, or hydrated iron oxide (limonite). Examples of the deposition of sulphur may be found at almost any sulphur spring or well, but lime and iron deposits are less common. The subject of deposition in crevices and caverns has already been considered in the discussion of cavern formation.

---

[1] Heilprin, Angelo. Explorations on the West Coast of Florida, Wag. Free Inst. Sci., vol. i, 1887, pp. 57-58.

[2] Dall, Wm. H., Neocene of North America, U. S. Geol. Survey, Bull. 84, 1892, p. 153.

In the first annual report[1] of this Survey, mention was made of the occurrence of sulphur near Floral City, and it was suggested that the deposit may have been the result of the decomposition of hydrogen sulphide gas escaping from underground waters.

Human Remains: — For many years Florida has proved a very important collecting ground for human relics. Both sand and shell mounds are common along the coast; and sand mounds occur at many localities on the banks of the principal streams farther inland. Some of the sand mounds appear to have been used for dwelling places while others served as burial grounds. Several accounts have been published, describing the skeletons, implements and pottery obtained by excavating in these mounds; and a partial list of the papers may be found in the bibliography accompanying Moore's paper in the Journal of the Academy of Natural Science, Philadelphia.[2] Apparently all of the mounds are built of Pleistocene sands or shells of living species of mollusks, and they are doubtless of Recent age.

In 1871, attention was drawn to a skeleton which was found by Mr. J. G. Webb near Osprey, Manatee County. Subsequently, other human remains were discovered in the same county. The exact localities are[3]: the farms of Mr. J. G. Webb and of Mr. J. W. Webb, both near Osprey; Hanson Landing; 8 miles north of Osprey; and 1½ miles south of Osprey.

Chemical analysis showed that the bones had undergone considerable change, especially in the dimunition in the phosphates and other compounds of lime, and a corresponding increase in silica and iron. The increase in iron was notably large, and there were other changes which seemed to show a marked antiquity of the remains.[4] However, the close resemblance of these remains to recent Indian bones, appeared to contradict the chemical evidence.

In consequence of the importance of the find, the locality was visited by Dr. T. Wayland Vaughan, of the United States Geological Survey, and his report, which is summarized here, is published in full in the paper cited above.[5]

Osprey is situated on a narrow tongue of land rising some 15 to 20 feet above sea level, about one-third of a mile long and from 100 to 150 feet wide. The

---

[1] Sellards, E. H., First Annual Report of Florida State Geol. Survey, 1907-1908, pp. 44-45.

[2] Moore, Clarence B., Acad. Nat. Sci., Journal, Philadelphia, vol. xiii, 1908.

[3] Hrdlicka, Ales. Skeletal Remains in North America, Smithsonian Institution, Bureau of American Ethnology, Bull. 33, 1907, pp. 53-64.

[4] Ibid. p. 57.

[5] Ibid. pp. 64-66.

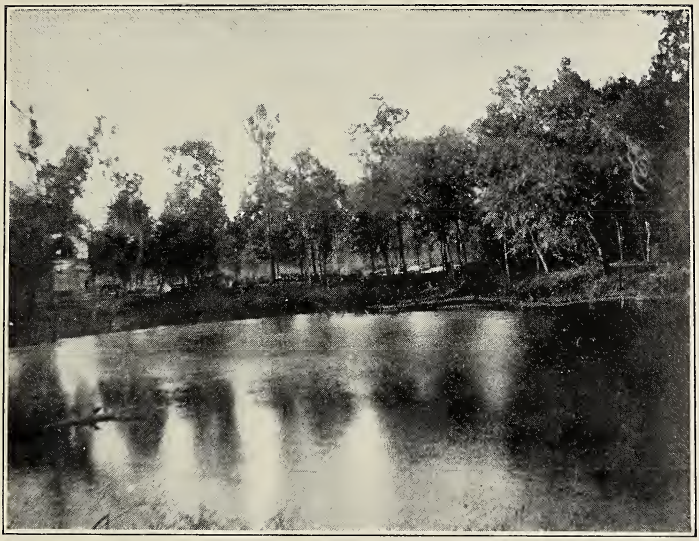


Fig. 1.—"RISE" OF THE SANTA FE RIVER, FLORIDA. THE STREAM ENTERS THE GROUND TWO OR THREE MILES AWAY, EMERGING AGAIN AT THIS POINT.

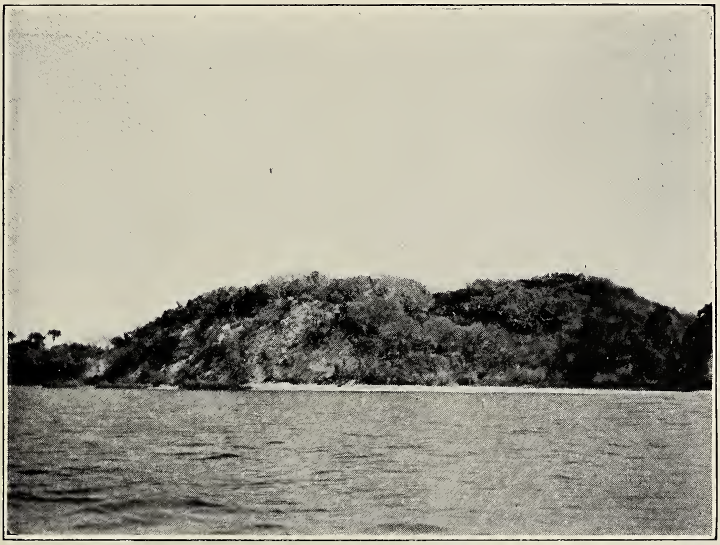


Fig. 2.—TURTLE MOUND (ANCIENT SHELL MOUND) ON NORTH INDIAN RIVER, FLORIDA.

ridge of the tongue is formed by an Indian shell mound. There is an Indian burial mound at its base, on its northeast side, and about one-fourth of a mile east of Osprey. Portions of a skeleton enveloped and partly replaced by limonite were found at this locality. Dr. Hrdlicka had a pit about 3½ feet deep dug at this place, and exposed the following section:

4.	Black soil, about	1 foot.
3.	Grayish or white sand, about	2 feet.
2.	Irregular bed of yellowish sand, continuous with the above	a few inches.
1.	Greenish, argillaceous, and sandy layer.—Thickness unknown.	

The yellowish sand is the layer in which the skeleton was found.

A study of the lower end of the shell mound on its side next to the bay gave the following section:

4.	Black soil	Several inches.
3.	Shells, numerous species, all of which are recent, about	4 feet.
2.	The base of the mound contains shells, many of which are cemented together and filled with ferruginous sandstone; others are filled with greenish sand. All stages from the green sand to the ferruginous sandstone are represented. The layer is not uniformly developed, occurring only in places	6 inches.
1.	Green sand to the water level in the bay.—Thickness undetermined.	

A collection of shells was made from numbers 2 and 3 of the section and were determined by Dr. Wm. H. Dall.

All the species found in No. 2 were also found in No. 3, and all of them are recent.

The geologic age of 2 and 3 is post-Pleistocene. Both from the contained fossils and stratigraphic relations they are younger than the Pleistocene of North Creek. The material in which the fossil human remains were found in the old burial mound seems to correspond to the ferruginous layer at the base of the shell mound, and can scarcely be older—that is, the human remains are post-Pleistocene in age.

Conclusions as to the Age of the Human Remains.

1. No importance can be attached to the fossilized condition of the human remains found at any one of the three localities studied.

2. At Osprey, where paleontologic and stratigraphic evidence is available, the evidence is in favor of the human remains being geologically recent.

3. Positive paleontologic and stratigraphic evidence is absent at the locality between 1 and 2 miles south of Osprey and at Hanson's landing. In each locality, there is no evidence to favor the remains being geologically as old even as Pleistocene.

4. All of the positive evidence and the conditions under which these fossilized human bones were found in Florida favor the opinion that man geologically is a recent immigrant into that area.

For an account of human remains found on Rock Island in Lake Monroe, the reader may consult the First Annual Report of this Survey, p. 25, 1908.

GENERAL GEOLOGIC HISTORY.

The absence of pronounced deformation of the rocks and the low relief of the surface of Florida make it difficult to obtain continuous sections of beds. However, by observations of such exposures as are available and the study of samples of strata procured from wells, it has been possible to obtain a fairly complete knowledge of the thickness, character and relations of the successive formations from the early Oligocene down to the present time. This knowledge permits the formulation of a general sedimentary history of the State from the deposition of the oldest rocks exposed to the formation of the sand dunes and coquina of the present day.

As a result of the studies already made, certain broad generalizations relating to the changes that have taken place are possible, one of the most important being that the older rocks of the State were formed under conditions which were uniform over wide areas and which permitted the deposition of several hundred feet of homogeneous sediments, while the younger formations were laid down under conditions which varied greatly within short distances, and changed at frequent intervals. That the period of deposition of the Vicksburg group was a time of great uniformity in conditions over wide areas is well shown by the remarkable homogeneity of the beds of this age which underlie practically the entire State. These beds are uniformly fine-grained and show little variation in chemical composition. There is a predominance of limestone, though sand and clay occur in small quantities, and the percentage of these impurities in the limestone increases in the upper beds of this age. There is also an increased percentage of terrigenous material toward the northern end of the State, where the proximity of older land, afforded opportunity for the entrance of considerable sand and mud into the Vicksburg sea. Toward the close of this period of deposition there appears to have been a shoaling of the seas which permitted the entrance of the fresh-water shells and the land-derived sediments noticeable in the Ocala limestone of the Vicksburg group. The excellent state of preservation of many of these shells shows that the water must have been comparatively quiet during the deposition of the limestone. The inclusion of a small percentage of land-derived sediments and in some places of fresh water shells shows that a portion of the limestones of Vicksburg age were probably deposited at no great distance from land. Locally the calcareous sediments appear to have contained large quantities of silica, probably in the form of tests of microscopic plants (diatoms) and spicules of sponges.

Recent studies of materials obtained from the sea bottom among the Florida keys have shown that there is a large amount of silica present. The number of samples collected was forty-seven and over 250 slides were examined microscopically. In one of the samples, which consisted largely of quartz sand, no tests of diatoms or spicules of sponges were seen, but in the other samples remains of these organisms were very numerous. The conditions governing sedimentation along the southern end of Florida are probably similar to those that prevailed during the Oligocene except that coral reefs were wanting in the Tertiary era. The shallow Vicksburg sea was apparently comparatively free from sand and mud and the greater portion of the sediments consisted of finely divided calcium carbonate containing organic remains. The silica which occurred in this material, being amorphous, was readily dissolved by percolating waters and subsequently deposited, replacing the calcium carbonate of the limestone. This process appears to have been quite active, for beds of chert a fraction of an inch to several feet in thickness are found to be very persistent at certain horizons. In fact, it is the chert beds which form the confining strata above the artesian water horizons. The cause for these beds being persistent over large areas is perhaps to be found in the deposition of large amounts of silica in certain horizons during sedimentation, though it is more probable that the silica was originally distributed throughout the limestone and the chert beds merely represent the horizons along which the silica-bearing solutions circulated most freely.

Toward the close of the period of the deposition of the limestones of the Vicksburg group, a partial emergence of the land was foreshadowed by the increase of terrigenous sediments, and the appearance of fresh-water shells which were doubtless washed into the sea from adjacent land areas during the deposition of the Ocala limestone. The extent of this emergence can only be conjectured, but it doubtless affected a considerable area north of Lake Okeechobee and it probably extended somewhat beyond the present boundaries of the State.

The nature of the movement which closed the period of deposition of the Vicksburg group is somewhat obscure, though it was probably a continuation of the broad arching of the strata which had been initiated during an earlier epoch when the structural basin of the Gulf of Mexico was first formed. The irregularity of the surface of the rocks, belonging to the Vicksburg, along the east coast is in part due to the deformation which took place at this time, and in part to subsequent erosion. Following this emergence there was a period of denudation when the surface of the land was carved into hills and valleys. The evidence of this erosion interval is found in the uneven surface upon which the later beds were deposited. When compared with mountainous regions the relief of the surface, produced during the interval of erosion, was insignificant, though it may have been sufficient to be comparable with that of the same region today.

The erosion interval was followed by a period when the sea once more encroached upon the land to such an extent that a large part of Florida was probably submerged. During this time considerable thicknesses of clay, sand and calcareous mud were laid down in the shallow water. In the east and south central portions of the peninsula the clay and sand predominated during the earlier part of this epoch, while farther north and west similar deposits characterized the later stages. The calcareous materials, which are found now in the form of marls and limestones were especially important in the area now drained by the Apalachicola River, but they were also deposited in smaller quantities farther south and east. Throughout the period represented by the Apalachicola group the conditions governing deposition appear to have differed considerably in neighboring localities, but there was no such abrupt variation as may be found along the present coast. The changes from sediments of one character to those of another were frequently rapid, and during the entire time there was more or less intermingling of different kinds of sediments giving rise to the marls, impure limestones, shales, and sands of this epoch. The fullers earth beds which occupy considerable areas in the north-central part of the State represent short intervals of uniform conditions controlling sedimentation, but these alternated with conditions which permitted the deposition of sands and ordinary clays. In general, the rocks of the Apalachicola group appear to have been marine, but during the latter part of the epoch some non-marine sands were laid down in the Apalachicola valley. At this time, the central portion of the Florida peninsula appears to have been an island which was separated from the mainland to the north by a shallow passage known as the Suwanee Strait.[1]

The Hawthorne formation which is largely clay, appears to have been deposited in the eastern part of this strait, while farther west the deposition consisted of limestone and marl. At certain localities the conditions were especially favorable for the development of organic life and hence some beds are very fossiliferous, notable examples being the "silex bed" at Tampa, the Chipola marl, the Oak Grove sand and the Shoal River marl members of the Alum Bluff formation. Associated with the other fossils in the silex bed there was probably a large quantity of amorphous silica in the form of sponge spicules and tests of microscopic plants. Subsequent solution and redeposition of this silica has given rise to the silex. Silica is also present in the limestones at other localities, especially in the central part of the peninsula, but it is, in general, much less abundant than in the limestones of Vicksburg group.

---

[1] Dall, Wm. H., Neocene of North America, U. S. Geol. Surv., Bull. 84, 1892, p. 111.

The period of deposition which is represented in the beds of the Apalachicola group, was terminated by an emergence of the northern and eastern parts of the State, but deposition may have continued on the southern margin of west Florida, where there is some evidence of a gradual transition between the Oligocene and Miocene beds. The amount of erosion which took place at this time can not readily be determined, but the faunal break is so marked that it indicates important changes in the physical geography of the continent. It is not possible to state just how much Florida was affected by the forces which produced the changes then taking place in the West Indies and Panama, but its general altitude was probably considerably altered by the earth movements which caused these changes. The elevation of the Isthmus at the close of the Oligocene affected Florida indirectly by changing the direction of ocean currents and thus producing a marked change in the fauna of the Miocene beds. Of the faunal changes at the close of the Oligocene Dall says:[1]

> As indicated by the changes in the fauna, the physical changes attending the close of the Oligocene were at first slow, allowing a certain element of transition to appear in the Oak Grove or uppermost Oligocene fauna. At the last they appear to have been sudden, at least the change in the fauna on the Gulf coast was absolute and complete. The change was not only in the species and prevalent genera of the fauna, but a change from a subtropical to a cool temperature association of animals. Previously, since the beginning of the Eocene, on the Gulf Coast the assemblage of genera in the successive faunas uniformly indicates a warm or subtropical temperature of water, and the sediments uniformly show, from the Jacksonian upward, a yellowish tinge due to oxidation. In the Oak Grove sands come the first indications of a change towards the gray of the Miocene marls. With the incursion of the colder water the change becomes complete. Not only do northern animals compose the fauna, but the southern ones are driven out, some of them surviving in the Antilles to return later. Some change along the northern coast permitted an inshore cold current to penetrate the Gulf, depositing on the floor of the shallow Suwanee Strait, separating the island of Florida from the continental shore, a thin series of Miocene sediments, which were also carried as far south as Lake Worth on the east coast of Florida and Tampa on the west coast, as shown by artesian borings.

At the close of the Oligocene the State of Florida appears to have had the same general form that it now has though its area was doubtless less than it is at the present time. With the inauguration of the Miocene there came a submergence which appears to have reduced the land area to a narrow strip along the northern end of the

---

[1] Dall, Wm. H., Wagner Free Institute of Science, Trans., vol. iii, pt. 6, 1903, pp. 1549-1550.

State and a peninsula which was both shorter and narrower than it is at present. During a part of this period the central portion of the peninsula may have been separated from the mainland by a shallow strait. The exact extent of the encroachment of the sea during Miocene times is difficult to determine because the deposits have been partially removed by subsequent erosion and their present extent is often obscured by considerable thickness of younger beds.

During the deposition of the rocks belonging to the Miocene, the conditions in East and West Florida appear to have been unlike. In West Florida and as far eastward as the St. Johns valley south of Palatka, the sediments consisted of soft shell-marls containing a high percentage of sand and clay. The character of the materials show that this marl was a shallow-water deposit which accumulated in such close proximity to the shore that a large proportion of the sediment is of land origin.

In the northern part of the St. Johns valley and extending southward along the east coast to near Lake Worth the Miocene is represented by an accumulation of sand and clay interbedded with more or less impure limestone. These sediments reach a thickness of nearly 500 feet at Jacksonville, but decrease toward the south. Limestone beds predominate toward the top of this formation, but they are also found at various other horizons. As in the preceding period, there appears to have been considerable amorphous silica deposited in the Miocene. This silica was subsequently redeposited in the form of chert beds replacing limestone, and where the original limestone was sandy the resultant rock resembles a coarse quartzite. The marked thickening of this formation toward the north is probably due, in part, to the proximity of large land areas to supply the sediments, and, in part, to deposition upon an uneven surface of the Oligocene limestone.

During this period the Suwanee Strait became closed, and the non-marine sedimentation extended southward over considerable areas of Oligocene rocks. These sediments form part of the thick deposits of sand and clay which extend from the northern boundary of the State southward nearly to the outcrops of the Miocene marls. This period of deposition was terminated by an emergence which was probably a renewal of the same processes of deformation which had been taking place since the early Oligocene.

The deposition of the rocks of Pliocene age began with an encroachment of the sea upon the margin of Florida until it probably covered all of the southern end of the peninsula and extended northward beyond the latitude of Lake Okeechobee. On the east coast the Pliocene sea occupied all of the St. Johns River valley and it may also have covered all of the land east of this river. The margin of west Florida was doubtless submerged, but the western margin of the peninsula from Tampa northward nearly to the Apalachicola River may have been out of water. This is inferred from the fact that the surface formations in that region are Oligocene. However, it is possible that the absence of marine Pliocene beds is due to post-Pliocene erosion rather than to non-deposition.

During the Pliocene there was extensive deposition of the non-marine beds which are known as the Bone Valley gravel ("land pebble phosphates") and the Lafayette formation. The conditions which permitted the deposition of these formations appear to have been low altitude of the land and the consequent accumulation of the products of mature weathering followed by an increase in altitude which stimulated erosion and caused the streams to remove, assort, and redeposit these weathered materials in their present position. That there was complete weathering of the rocks from which the materials of the Bone Valley and Lafayette formations were derived is shown by the fact that these formations contain the comparatively insoluble phosphate of lime, left by the solution of the limestones, and the sands and clays which are the results of the decomposition of other rocks and are not themselves subject to further weathering. The accumulation of such large quantities of residual products must have taken place under conditions which did not permit of their ready removal, and such conditions would be most likely to be low altitude which accompanied the Pliocene submergence, together with abundant heat and moisture.

After the accumulation of the weathered materials, an increase in altitude was necessary to permit their removal and deposition in their present positions. Evidence of the stream action is found in the poor assortment of both the Bone Valley and Lafayette formations and the cross-bedding of the sands and gravels of the latter. The increase in altitude appears to have been most marked at some distance from the coast, for the clays, sands and gravels which make up these formations would have been transported to the sea if the increase had been uniform.

Following the deposition of the Pliocene there was an emergence of the land which not only included the greater part of the present surface of the State, but probably included a portion of the area which is now submerged. This emergence is regarded as the beginning of the Pleistocene, though it might with equal propriety be regarded as the closing epoch of the Pliocene. This emergence gave the streams erosive power, and caused extensive dissection of the Pliocene and older formations. It was during this period of erosion that the major features of the present topography were produced. Concerning the extent of the emergence there is considerable diversity of opinion; and for this reason the views of some of the authors who have discussed the subject will be outlined below.

Such a Pleistocene elevation as has sometimes been advocated would have united Florida with the island of Cuba, but in the course of his investigations of the geology of Cuba, Hill[1] found no evidence of there ever having been such a land connection between the island and Florida. Moreover, the Island of Cuba, according to this author,[2] since the beginning of the Pleistocene has undergone comparatively slight changes of level. It is also worthy of note that the geology of Cuba indicates that its history has been very unlike that of Florida.

A factor bearing on the question of an extensive emergence of Florida has been presented by Shaler,[3] who called attention to the fact that though the sediments of northern Florida and the adjacent States are marine they have been drained of their original content of salt water to a depth of nearly a thousand feet. In a later paper Shaler repeats the statement given above as evidence of recent extensive emergence of the peninsula of Florida, and also calls attention to the large submarine springs off the coast. He considers that these facts together with the estuariene character of the lower portions of the stream valleys indicate a subsidence of the land since the extensive uplift. That both emergence and subsequent submergence have taken place since the late Pliocene will scarcely be questioned. The only point in dispute is the magnitude of the movement.

The best known of the submarine springs is situated near St. Augustine. According to Captain E. C. Allen, of that city, the orifice of the spring is about sixty feet across and the depth is about 200 feet. The depth of the sea at the point of emergence is said to be about fifty feet and the water emerges with enough force to cause a distinct convexity of the surface during calm weather. According to some authorities, it is difficult to row a small boat across the surface above the spring on account of the outward movement of the water from above the orifice.

There is no doubt that the marine strata of Florida contained salt water at the time of their deposition, and there is good evidence that the beds beneath the central part of the State have been drained of this water to a depth of several hundred feet. Owing to the fact that the deep wells have seldom been cased more than 200 to 300 feet it is difficult to determine the character of the water encountered at great depths because, in practically all cases, considerable fresh water enters the well near the surface and this would serve to dilute any salt water which was obtained below, and moreover, unless the head of the deep supplies was greater than that from shallower water bearing horizons, there would be a downward movement of the fresh water from the higher to the lower beds. However, the apparent absence of salt water in the deep wells of the northern part of Florida suggests that their included sea water has probably been drained out. The exact depth to which this process has extended is somewhat uncertain. Shaler's estimate of nearly 1,000 feet is probably too low rather than too high for in a well at Sumterville hard sulphur water was encountered at 1,386 to 1,400 feet and although the well was continued to a depth of nearly 2,000 feet no deeper supplies were encountered. At Ocala, the well of the City Water Co. which is cased to a depth of 1,250 feet, did not encounter salt water. However, in passing from the central part of the peninsula toward the coast salt water is frequently encountered at a depth of a few hundred feet and in some wells the salt water comes from a depth of less than 100 feet. The salt water in the shallow wells may be explained by supposing that it entered the porous beds during the Pleistocene submergence and has not yet been drained away. The presence of salt water in the deeper wells near the coast may be interpreted in the same way, but the explanation is much less certain than in the case of the shallow wells; and, possibly some of the saline waters of the deeper wells is sea-water included in the sediments when they were deposited. The deep wells all penetrate the limestones of Vicksburg age, and hence it is the beds of that age which have been drained of salt water. As a portion of these beds have been above sea level since Oligocene time, the salt water may have been removed before the Pleistocene. The magnitude of the emergence is not necessarily so great as 1,000 feet, because, given the necessary chance for escape the salt water would probably be displaced by fresh water, provided the surface was high enough to afford a small hydrostatic pressure. The absence of impervious beds of clay above the submarine portion of the Oligocene limestones would permit the escape of the water, and hence considerable thicknesses of the older rocks may have been filled with fresh water without being raised much above their present altitude.

---

[1] Hill, Robert T. Notes on the Geology of Cuba, based upon a reconnaissance made for Alexander Agassiz, Harvard Coll. Mus. Comp. Zool., vol. xvi, No. 15, p. 285.

[2] Ibid., pp. 243-288.

[3] Shaler, N. S. Note on the value of the Saliferous deposits as evidence of former climatic conditions, Boston Soc. Nat. Hist. Proc., vol. xxiv, 1888-1890, p. 584.

Since it is doubtful if the formation of large underground channels extend to great depths below sea level, the large springs point to considerable emergence. This emergence must have been of comparatively recent date, as, otherwise the openings would have been choked during the deposition of the younger Tertiary formations. These facts suggest that the channels of the springs were formed during the post-Pliocene. It is believed that they date from the uplift which permitted the erosion of the deep valleys of the large streams of northern Florida.

Concerning the probable changes of level in Florida Dall says:[1]

> The, on the whole, remarkable horizontality of the Florida strata indicates a freedom from violent changes of level from the time the Peninsular limestone first emerged from the sea. Landshells in the Ocala limestone show that then dry land existed. South of the Suwannee Strait, closed in late Miocene times, there is no evidence of subsequent submersion to any serious extent. Two gentle flexures run parallel with the peninsula, having the lake district between them; a tilting of, at the most, thirty feet, up at the east, down at the west, which may have been contemporaneous with the flexures; and, for the rest, very slow and slight but probably nearly continuous elevation never exceeding one hundred feet and perhaps less than half that, with dry land and fresh-water lakes constantly existing since the Ocala islands were raised above the sea; such is the geological history of the Florida peninsula. Denudation of the organic limestones by solution rather than erosion is the prominent characteristic of the changes in the surface. Soft, crumbling under the finger-nail the rocks of the plateau, if lifted five or six thousand feet, as claimed by Dr. Spencer, would have been furrowed by canons and swept bodily into the sea. Indeed, to me the proposition is inconceivable as a fact and incompatible with every geologic and paleontologic fact of south Florida which has come to my knowledge.

If the Lafayette beds which form the surface of considerable areas in north Florida were deposited when the surface had a low altitude, the subsequent uplift, to permit the streams to cut their valleys to their present depth, would amount to approximately 250 feet near the northern line of the State; and since the streams appear to have cut below the levels of their present flood plains this estimate may be regarded as too low by an amount which, owing to the absence of satisfactory data, is yet undetermined but is probably not great.

The erosion interval which began in the early Pleistocene or late Pliocene, was succeeded by a slight submergence which permitted the sea to cover the southern end of the State northward to some distance beyond Kissimmee, though the ridge upon which Lakeland is situated probably remained out of water either in the form of an island or a long, narrow peninsula. The St. Johns valley was also occupied by the sea and the land to the east of it may have been again submerged. A strip of land of varying width along the Gulf coast was also covered and the sea extended into the valleys of all the large streams forming estuaries which were more extensive than those of the present day.

During the interval of extensive erosion the Lafayette upland had been considerably dissected and its materials had been deposited in the valleys which were being excavated. With the inauguration of the cycle of submergence there was a large addition to the detrital surface materials in the form of coarse-grained, white sand. The extent of the submergence is undetermined, but it probably covered the major portion of the surface which lies below the 100-foot contour, and it is possible that the submerged tract was somewhat greater.

---

[1] Dall, Wm. H.,Tertiary Fauna of Florida: Wagner Free Institute of Science, Phila., vol. 3, pt. 6, 1903, pp. 1545-1546.

The submergence was of short duration, and was followed by an emergence which was sufficient to expose an area somewhat beyond the present margin of the State. In discussing the physical changes, it has hitherto been necessary to mention only the broad changes, because the details of successive movements have not been recognized, but in the case of the Pleistocene submergence certain minor details have been preserved. These are in the form of marine terraces which represent periods when the relation between the land and sea remained uniform long enough to permit their formation. (See Fig. 2, Plate VI.) The most pronounced terrace observed during the recent field season is about twenty-five feet above sea level, but there is at least one and perhaps more at higher levels. It is to be hoped that the completion of topographic surveys similar to those in other States of the Coastal Plain will enable the geologist to discriminate these terraces; but at present the absence of satisfactory contour maps makes their study impracticable.

The slight submergence which has taken place in comparatively recent times has permitted the sea to enter the lower portions of the stream valleys and has covered a narrow belt of land along the entire coast. The small submerged valleys along the west coast were doubtless carved during the uplift just preceding this submergence. That the movements which have taken place have not always affected the entire State uniformly appears probable, and this recent submergence of valleys on the west coast has been regarded as an example of unequal movement. The following statement by Dall[1] illustrates one of the views which has gained wide credence:

> The mapping out of the distribution of the different geological horizons from many isolated observations, a good number of which were by Mr. Willcox himself, as shown on the map in Part II, taken into consideration with the observation of Shaler and others on the east coast, indicated that the peninsula of Florida has experienced a tilting by which the eastern margin has been elevated between twenty and thirty feet, while the western coast has been depressed about the same amount. This tilting is supposed to have taken place since the Pliocene. To the data of 1891, upon which the above generalization was based, Mr. Willcox has lately added observations which still further emphasize the fact. He finds that, off the streams falling into the Gulf of Mexico from the peninsula in the relatively shallow waters over the submerged plateau to the west, chan-

---

[1] Dall, W. H., Tertiary Fauna of Florida. Trans. Wagner Free Inst. of Sci., vol. iii, pt. vi, 1903, p. 1544.

nels cut in the limestone may be traced for some distance. As these channels, too small to make any marked feature on the usual hydrographic chart, could not have been cut since the sea has covered the plateau, the inference is obvious that they were cut before the tilting of the peninsula, when the limestone was above the level of the sea.

The drowning of the St. Johns River valley which permitted brackish water to extend far inland, beyond Jacksonville, shows that the east coast as well as the west has recently been depressed. The amount in either case was probably comparatively slight though it is difficult to obtain precise data. However, since the channel of the St. Johns River has a depth of at least sixty-five feet below mean tide opposite Jacksonville it is safe to assume a depression amounting to over fifty feet. An equal amount of submergence is suggested by the depth of water covering the submarine spring near St. Augustine, and a far greater depression is suggested by the depth of this spring which, as already noted, is reported to be 200 feet; but this greater submergence probably took place before the deposition of the Pleistocene sands and marls.

Earth movements are doubtless taking place along the coast of Florida at the present time, but the rate of change is so slow that it is only under the most favorable conditions that the effects of the movements are noted. One of the earliest recorded observations on coastal changes was made by Dr. Gorrie[1] in 1884. According to this writer the coast at Apalachicola was gradually sinking during the twenty years preceding 1854. The evidence upon which the conclusions were based was the increased depth of water of the bar at the South Pass to Apalachicola Bay, and the submergence of tree trunks and roots, and permanent submergence of oyster reefs that were formerly exposed at every low tide. The increase in depth of water over the bar at the entrance of the harbor might be accounted for by the action of waves and currents. If the water of the bay was prevented from escaping readily it is possible that the water level might have been raised slightly, but the deepening of the pass across the bar should have furnished a free passage for the water, and hence the submergence of trees and oyster reefs was probably due to an actual change in the level of either land or water. The amount of submergence was estimated at eight or nine inches in twenty years, or approximately seven feet per century.

In 1902, Vaughan[2] obtained information which indicates that the coast in the vicinity of St. Marks has been rising within the last half century. The evidence shows that a small pond which was formerly overflowed at high tide is now entirely drained and is not invaded by the sea except at high tide and after a strong on-shore wind has been blowing for at least two days. In 1902, the ordinary high tide was reported to fall 300 yards short of reaching the pond, in spite of the fact that the connection with the sea was less obstructed than formerly. This change which is estimated at from one to one and a half feet since the "fifties" is thought to indicate an emergence of the land at the rate of two to three feet per century.

---

[1] Gorrie, Dr. On changes of level of the western Coast of Florida, Boston Soc. Nat. Hist. Proc., vol. 4, 1854, pp. 391-392.

[2] Vaughan, T. Wayland. Evidence of recent elevation of Gulf Coast along the western extension of Florida, Science, n. s., vol. 16, No. 404, 1902, p. 514.

Considering the two cases described above, there are found to be two opposite movements represented within a short distance of each other. At Apalachicola the observations cover about twenty years prior to 1854 and at St. Marks they cover the last half of the century. Granting that observations recorded should be given full credence, there still remains a question as to whether there was a change in the direction of movement about the middle of the century, or whether there are two opposite movements on the same coast.

The only record of recent movements on the east coast is contained in a brief note by Lewis.[1] This writer reports the submergence of stumps of cedar trees at St. Augustine. The amount of the movement is not recorded.

The recent geologic and topographic changes of importance consist of the deposition of coquina, sand, marl, peat and muck, and the formation of sand dunes and ridges. There is a rapid deposition of sand and coquina taking place along both the Atlantic and Gulf coasts and more or less marl and partially decomposed organic matter, in the form of peat and muck, in the marshes and lagoons. The formation of dunes and ridges of sand is especially active along the east coast as far south as Hobe Sound, and a similar action, on a much smaller scale, is taking place in the interior of the State. Solution and the consequent formation of underground channels, sink holes and natural bridges doubtless began with the emergence of the calcareous rocks and it is still going on. The effects of solution are shown by the emergence of water bearing mineral matter in solution and by the occasional subsidence of small areas.

---

[1] Lewis, E. Evidence of a probable modern change of level on the coast of Florida, Am. Jour. Sci., 2d ser., vol. 41, 1866, p. 406.

THE TOPOGRAPHY AND GEOLOGY OF SOUTHERN FLORIDA

BY SAMUEL SANFORD.

THE TOPOGRAPHY AND GEOLOGY OF SOUTHERN FLORIDA

SAMUEL SANFORD.

INTRODUCTION.

The term Southern Florida is here made to include, for convenience of description, that portion of the mainland with its bordering islands or keys that lies south of a roughly northeast-southeast line extending from the north line of Palm Beach County on the east coast past the south end of Lake Okeechobee to the mouth of San Carlos Bay on the west coast. The piece of mainland thus arbitrarily cut off has an extreme length, north and south, of 140 miles, and a greatest width, east and west, of 120 miles. Its area is about 7,300 square miles, of which 6,000 square miles are swamp or land so low lying as to be covered with water during the rainy season, June to October, or unusually high spring tides. The total number of the keys is unknown, but their area is here estimated at 300 square miles.

Growing coral reefs extend along the Florida coast for over 200 miles and are found nowhere else in the continental limits of the United States. Because of the reefs and the teeming marine life of the surrounding waters, Southern Florida has attracted attention for over fifty years and has been visited by a number of eminent men who have described and discussed the main features of the chain of keys and the southeast shore of the mainland. Owing to the difficulties of getting about in this region and its comparative remoteness and inaccessibility before the building of the Florida East Coast Railway, these visitors confined there observations largely to the reef, the shore line of the keys and the edge of the mainland in the vicinity of Biscayne Bay.

While acting as geologist of the Key West Extension of the Florida East Coast Railway in 1907 and 1908, the writer had an opportunity to study in detail some features of the topography and geology that were not so evident in former years as they are today. Since the last important contributions to the geology of the region, the paper by A. Agassiz[1] on the elevated reef, and that by Griswold[2] on the southern Everglades the railroad has been completed from Palm Beach to Miami, and from Miami to Knights Key. At the mouth of the Miami River, where were but a few houses at the time of Griswold's visit, there is now a city of over 5,000 inhabitants, from which radiate miles of excellent macadam roads. Where was then a barren wilderness are now thousands of acres of truck farms and orange and grape fruit plantations. The result to the geologist from this transformation is a great increase in the easily obtainable rock evidence. Wells, quarries for road metal and railroad borrow pits make the compiling of geologic data along the east coast vastly more easy than it was fifteen years ago. Even on the west coast from Cape Sable north, there are more settlements today than there were then and with the coming of the motor boat, the exploration of the shallow and tortuous passages characterizing that coast has been much facilitated.

---

[1] Agassiz, Alexander. The Elevated Reef of Florida, Mus. Com. Zool. Bull. xxviii, No. 2, 1896, pp. 29-51.

[2] Griswold, Leon S. Notes on the Geology of Southern Florida. Mus. Com. Zool. Bull. xxviii, No. 2. 1896, pp. 52-59.

The larger portion of the interior is included in the great saw-grass swamp of the Everglades. Though well known to many white men living on its borders, hunters of alligators and plume-birds, this vast expanse of water and sedge-covered muck has been visited by few geologists and traversed by none. Griswold's account of what he saw in the southern 'Glades remains the best description of the more noteworthy features of the topography and geology of that region as yet written. Pending the completion of a comprehensive survey for the control of drainage and reclamation projects our knowledge of the geology of the Everglades is not likely to be greatly increased, since the individual explorer, owing to the physical difficulties cannot accomplish much.

ACKNOWLEDGMENTS.

The writer takes this opportunity to thank various gentlemen who have given him data or useful suggestions. In particular he expresses his gratitude to Dr. J. N. MacGonigle, of the Florida East Coast water companies, J. E. Ingraham, of the Florida East Coast Railway, and J. C. Meredith, constructing engineer, and W. R. Krome, principal assistant engineer, of the Key West Extension. He is indebted to T. Wayland Vaughan, supervising geologist, U. S. Geological Survey, for data used in the preparation of this report and has frequently consulted George C. Matson, assistant geologist, while compiling data.

OBJECT OF REPORT.

The following brief account of the more important features of the topography and geology of southern Florida is based chiefly on data accumulated while in the employ of the Key West Extension of the Florida East Coast Railway, supplemented by hasty trips along the West Coast and the East Coast. Being based on a mass of information that could not or would not have been collected before the advance of the railroad along the coast and across the keys, it is natural that some of the conclusions expressed may controvert those of writers who had to rely on more limited observations and had no way of knowing what was beneath the surface. Having lived for months on one of the keys and having seen some of the mainland the writer appreciates the disadvantages those who wished to get trustworthy data had to meet and overcome. In the preparation of this report he has aimed to give an easily understood account of the topography and geology of a fascinating region now easily accessible, and to indicate the bearing of the more striking features of the accumulated evidence on some geologic problems of importance. He has tried to present the more essential facts as briefly as is consistent with clearness. Hence he has given detailed evidence but seldom and has not discussed subjects that do not bear directly on the theme of his narrative. In particular he has not presented item by item the testimony for or against his conclusions on minor points. A number of interesting problems he has barely mentioned. These he hopes to discuss in detail elsewhere.

TOPOGRAPHY.

GENERAL FEATURES.

In a general review of the salient features of the topography of southern Florida, it is convenient to consider the mainland and the keys separately because on the mainland one can distinguish certain distinctly marked topographic units. Also, the features of the shore line may be taken up independently of the discussion of the varying forms of the land surface; for this reason the shore line topography is considered by itself, and as the subject is one of considerable interest on which little has been written, it is discussed briefly.

Taken as a whole the topography of the Florida mainland has all the aspects of infancy. Drainage is defective, sloughs, shallow ponds and lakes abound. Most of the interior is a swamp, there are no well defined river systems nor stream valleys, and some of the short rivers that flow from the Everglades into the Atlantic are, where bed rock comes a few feet above tide level, characterized by rapids in their upper courses.

This infantile aspect is due to two causes, one the actual recency of deposition of the beds, consolidated and unconsolidated, that constitute the land surface, and the other the slight elevation of the beds above tide level since deposition. The rocks have had relatively little time to decay, and there has not been an elevation of the land sufficient to give streams an opportunity to erode valleys and establish well marked drainage systems.

The shoreline topography has a more varied look, in places its form are those of infancy, in places, of youth or adolescence; these differences are due to the mastery of causes that tend to extend the land's edge irregularly, or to the control of those that smooth shore lines into long sweeps and easy curves.

Shape of the Land Mass.—The relations between land and water shown by the maps of any coast are inconstant and ever varying. Not only is the shore line a line of battle between the forces that destroy and those that build up the land, but geologic history shows that changes of level are the rule, that the lands or the oceans, slowly rise or fall during long periods of time, parts of the sea bottom becoming dry land, or the oceans invading the land over great areas. In places these movements are rapid enough to be proved by human records.

Where rocky highlands border the ocean, invasion is slow; where coasts are low, it is relatively swift. The transitions of coast lines, and the changes resulting from slight elevations or depressions of coast, are facts of high importance in contemplating the present shape of the land mass of southern Florida.

As has been pointed out by Dall and others, the present Florida mainland is but the top of a vastly greater submarine plateau, the southeastern and southern edges of which are near the present shore line, the western edge many miles to the west. Hence, we may regard the present outline of the Florida mainland as a mere accident. While stable enough when measured in terms of human life, it is ephemeral compared with the duration of a geologic period.

A depression of fifty feet would cover all the area considered in this report, except the tops of sand hills and ridges; an elevation of fifty feet would, from the configuration of the submarine plateau, extend the shore line but little on the east, though making dry land of Biscayne Bay; on the south it would dry the Bay of Florida; and on the west it would extend the land to forty miles west of the entrance to Shark River and twenty miles west of Cape Romano.

FEATURES OF THE MAINLAND.

While the surface of the south Florida mainland has slight relief yet it shows considerable variety of type. A detailed study of its forms is without the province of this paper, which deals primarily with geology, but various surface features will be discussed at some length because of their intrinsic importance, because of the attention given them by previous writers, and because a general understanding of the topographic types is essential in the study of the recently deposited formations.

Southern Florida lies low, the average elevation of the surface must be below 20 feet and over long stretches the ground is almost a dead level. The general slope of the surface is south with a very slight tilt to the west. This is shown by the drainage of Lake Okeechobee, the generally higher elevation of the land on the east than on the west coast, the greater length of the west coast rivers and the trend of the river courses, features that are considered individually on succeeding pages.

In consequences of the slight relief, imperfect drainage and resulting accumulation of surface water during the rainy season, small differences in height of surface may have a marked effect on vegetation, and hence it is possible roughly to divide the mainland into pineland and swamp, the former including the hammocks, isolated patches whereon grow hardwood trees of several genera, and many of the prairies or grassy tracts, and the latter the coastal swamps with their characteristic growths of sedges or black and red mangroves.

The line of demarcation between swamp and pineland, owing to the low relief, is extremely irregular and along it frequently extends a variable width of grass land or prairie, that at the end of a rainy season may be two feet under water, but in most years gets so dry during the winter months that tomatoes and other garden truck can be grown at a profit without artificial drainage.

PINELANDS.

The pinelands of southern Florida are not remarkable by reason of the size of the trees, the thickness of growth, or yield of good timber per acre, but as they include the larger portion of the surface lying above what may be termed normal water level they are impressive from their extent.

The total area covered by pine forests is a matter of conjecture, for though the pinelands have been surveyed by the United States Land Office, the township maps give an imperfect idea of the actual extent of the timber. In round figures possibly 1,300 square miles are to be regarded as pine-clad.

The pinelands of the eastern coast extend for the most part as a narrow belt, between the Everglades and the coastal swamp, from the north line of Palm Beach County to the vicinity of Homestead. This belt is widest at the north, where it may be twenty miles across, but is much narrower south of Jupiter Inlet, where it is about six miles wide, varying in width from two to eight miles to the southern extremity. On the west coast the pines are more irregularly distributed. There is no pineland south of Lostmans River. Along the north line of Monroe County the pines grow in more or less disconnected areas separated by narrow and broad strips of cypress. In the vicinity of Naples the pines grow to the shore of the gulf; between Cape Romano and the mouth of Lostmans River they lie from ten to fifteen miles back of the outer face of a network of keys that constitutes the apparent shore line.

As the trees grow on areas of quite different topographic aspect, the pineland of southern Florida may be divided according to the character of its relief into dunes, rolling sand plains, rock ridges and flat lands.

DUNES.

That there may be no misunderstanding as to the sense in which the word is used, a dune is here defined as a heap of wind-moved sand. In other words it is a purely aeolian accumulation of material, and is thus distinct from deposits of sand that owe their relief, wholly or in part, to the action of water, whether this action has been that of currents or of waves. Hence dunes are sharply differentiated from beach ridges, those coastal accumulations of sand and other loose material in the shaping of which waves and wind-driven spray took part. Thus the ridge facing the ocean at Palm Beach is not considered a typical dune.

In southern Florida the dunes lie near the coast. East of the Everglades and Lake Okeechobee they reach south to New River as a discontinuous series of irregularly distributed mounds and ridges, sometimes separated by considerable intervals of flat or gently rolling country, or by stretches of shallow water yet seldom reaching more than a few miles inland and but rarely facing the open ocean. South of New River there are, so far as the writer knows, no true dunes. There are certainly none on the long chain of keys that extend from Biscayne Bay to the Marquesas. The nearest approach to dunes to be found along that 150 mile stretch of islands are the low indistinct ridges and mounds nowhere eight feet above mean sea level, that are more pronounced along stretches of beach facing breaks in the living coral reef, particularly where the water near shore has more than average depth or rather where the seaward slope of the bottom is greatest. These low heaps of sand from their position may be the work of the waves quite as much as the wind, in fact most, if not all, are true beach ridges. Their outlines may possibly be modified slightly by the drift of wind-borne sand but their main features are clearly due to wave action, particularly to the waves that break on the exposed beaches during a hurricane when tides four feet or more above mean high water mark facilitate the formation of in-shore waves much higher than those that break on the beaches during the other days of the year.

On the west coast of Florida, south of the mouth of the Caloosahatchee River there are few dunes, and these do not face the open water of the Gulf.

The dunes are composed of medium fine quartz sand, varying in tint from pale yellow to orange or to light reddish brown. This sand is rather angular and occasionally can be broken down to finer grains by rubbing between the fingers. Fossil shells are rare, if present at all. The writer in a rather careful inspection of several sections through dunes saw none. The varying tints of the sand are not according to the writer's observations arranged in distinct bands nor is the sand everywhere plainly stratified. There is a tendency toward increase of color with depth below surface thus causing the coloration seen in a section through a dune to follow the surface contours. Also the shades of yellow and brown are frequently mottled or blotched. Streaks of gray sand, possibly caused by the decay of pine tree roots, extend a varying depth from the surface into the yellow and reddish sands below. In some instances toward the centers of dunes the sands may be so cemented by iron oxide as to form irregularly rounded masses of hard rock.

Along the east coast the position of the more prominent dunes near the shore is indicated on the Coast Survey charts. A noteworthy succession of ridges is the one that extends in an approximately north-northwest direction from two miles north of the dune, on which stands Jupiter lighthouse, at the north side of Jupiter Inlet, to and past Hobe Sound Station on the Florida East Coast Railroad. Just back of the station a summit of this series of ridges has a height of sixty-three feet above mean tide. Back of the lighthouse at Jupiter the top of one dune is perhaps forty-five feet high. Beyond Hobe Sound station the dune belt veers to the westward and dies away within three miles. There are no dunes along the railroad from Hobe Sound to the north line of Palm Beach County, and, according to report, no large ones north of the northern end of the Hobe Sound belt and no high ground between its northern end and Kissimmee.

South of Jupiter Inlet dunes are numerous, but occur as disconnected mounds or ridges, not as continuous or contiguous ridges. A typical dune forty-seven feet high at West Palm Beach, according to report, contained masses of rock. Isolated dunes and ridges near the shore between West Palm Beach and Jupiter are shown by the Coast Survey charts. South of West Palm Beach the dune belt lies farther inland, though generally parallel to the seashore, and the more prominent dunes have not been mapped. There is a fine dune ridge near the east side of Lake Osborne, about one mile west of Lantana Station. Isolated dunes of diminishing height occur to the south, the southernmost one known to the writer being Pine Island, in the Everglades back of Fort Lauderdale, six miles from their eastern margin. The belt of country containing the prominent dunes south of West Palm Beach probably in no place exceeds five miles in width.

On the west coast of southern Florida dunes are not nearly so numerous as on the east coast and are more irregularly distributed; like the east coast dunes, they are found near the shore, rather than inland.

The best developed dune-system on the west coast, seen by the writer, is the one that covers parts or the whole of several islands near Caximbas Pass. It extends east from the south end of Caximbas Island in a disconnected line having somewhat the shape of the Greek letter Ω, the total length being about eight miles. Just back of Caximbas postoffice at the west end of the system there is a dune about thirty-five feet high. A mile to the northeast is another ridge having a maximum height of sixty feet, and said to be the highest in the system.

There are no dunes on the islands near the mouth of Caloosahatchee River, where from the configuration of the present coast line they might be expected, although a high beach ridge forms the backbone of Captiva Island. Between the mouth of the Caloosahatchee and Caximbas there are said to be two dunes, one on a small inner key near Estero, the other, much larger, on the mainland about half way between Marco and Naples.

South of Caximbas there are no dunes, not even back of the ten-mile stretch of sandy beach at Cape Sable and none along the southern edge of the mainland from Cape Sable eastward.

It will be noted from this brief account of the distribution of the South Florida dunes that while their arrangement is in some way related to the present coast line, the relation is not a definite one. The high ridges lie back from the ocean and from the Gulf, yet extend but a few miles inland. Those lying on keys rise out of mangrove swamps where dune building is an impossibility; those near open water, like the dune back of Jupiter Light usually have a protecting key between them and the ocean and have a fringe of mangroves along the shore.

Perhaps the most noteworthy feature of the dunes of southern Florida is the slight movement of the sands today. Cleared of pine timber and palmetto scrub they grow good pineapples, but even when bare the sands are little moved by the prevailing winds. While the blasts of a hurricane may have some effect there is certainly nowhere in southern Florida any such movement of sand as is characteristic of dunes in active growth; there is no leeward march overwhelming trees and threatening dwellings; no such sand drift as can be seen at Cape Henry, Virginia, and at other points on the Atlantic coast. Instead of burying forests the dunes of southern Florida where not cleared, are covered with large pine trees. In short they are quiescent.

Evidently, therefore, the dunes were formed during a time when conditions were different from those now prevailing, a time when the land stood higher and the climatic conditions favored sand drift. Lying near the coast they are not directly related to the present shore line, but, as shown by the fringes of swamp and the off-lying keys, to another shore line now below sea level. The significance of these facts as bearing on the post-Tertiary history of southern Florida will be discussed later.

ROLLING SAND PLAINS.

This term is used to include those sandy stretches of the mainland having broad swales and low ridges. In the swales are shallow lakes or lagoons, wet prairies or cypress swamps. On the east coast these sand plains form a belt, having a possible maximum width at any one point of six miles, and extending from the north side of Palm Beach County nearly to Miami River. Out of this belt rise most of the dune mounds and ridges. Inland the rolling sand plains merge insensibly into the monotonous level of the flat lands and the prairies bordering the Everglades, seaward they are bounded by swamps, or by open water.

On the west coast south of the Caloosahatchee River rolling sand plains are of relatively slight importance, though under this head may be included the arable land, a succession of beach ridges, back of the present shore line at Cape Sable and the sandy keys often not pine clad fringing the coast from Cape Romano northward.

Near the shore on the east coast the higher ground and the ridges of the sand plains are frequently covered with a straggling growth of spruce pine. In the hollows are many fresh water lakes, some several miles long. Most of these are less than ten feet deep, and some are so shallow that they disappear entirely for months during such a period of deficient rainfall as prevailed from November, 1906, to May, 1908. A few of the lakes may be over ten feet deep and the writer was told that Lake Osborne had a maximum depth at the end of a normal rainy season of over twenty feet. However, the lakes as a rule are so shallow and their banks have such gentle slopes that a survey of the rolling sand plain country made in or shortly after a summer of normal rainfall would show vastly different relations of land and water than one made in early spring following a year of deficient precipitation. This accounts in part for lakes appearing on maps of southern Florida at places where the visitor may find none.

The character of the sands, the elevation and prevailing trend, parallel to the coast, of the ridges, indicate that the rolling sand plains are largely the work of the wind and that they are related to the dunes.

FLAT LANDS.

This term is applied to the imperfectly drained pinelands lying between the rolling sand plains and the Everglades or their bordering prairies, a discontinuous strip of country which on the east coast extends from the north side of Palm Beach County to the vicinity of New River in Dade County. Its greatest width back of Hobe Sound is about ten miles.

The flat lands have a soil of white sand, resembling that of the rolling sand plains, bearing a thin growth of pine trees separated in places by expanses of prairie a mile or more wide, a difference of a foot in elevation determining the character of the vegetation. In the rainy season these prairies are shallow lakes. In the flat lands are also occasional sloughs, pond holes, sometimes one-fourth mile or so across, which, being three to five feet below the general level of the country are never entirely dry. In places these deeper hollows support good growths of cypress, and as the region of relatively permanent standing water, the Everglades, is approached, the pine and the cypress growths intermingle in most irregular fashion. In some places pines grow up to the edge of the prairie bordering the Everglades, in others a fringe of dwarf cypress separates pineland and swamp, and in still others are considerable areas supporting a good growth of cypress.

On the west coast the surface of the country between the Everglades and the Gulf coast is even more monotonously level than on the east coast, the relations of swamp and dry land more irregular. Much of the pine grows in patches and strips sometimes miles in extent, separated by cypress swamps. In consequence the timber-clad flat lands of the west coast are described as pine islands and cypress strands. Prairies are scattered through or fringe the pinelands, and toward the Everglades and north of the Big Cypress are great stretches of prairie that make excellent cattle ranges.

ROCK RIDGES.

There is a striking absence of rock outcrops over the greater part of that portion of the mainland included under the term southern Florida. And this absence becomes remarkable when one finds that the presence of solid rock a few feet below surface can often be proved by sounding with a rod. To outcrops of any extent the term rock ridges is here applied, though it should be understood that these rock ridges may not rise more than two feet above the level of the surrounding country, and probably in no case have an elevation of thirty-five feet above mean tide.

The rock ridges of the east coast comprise the outcrops of oolitic limestone, which extend from north of Miami to Homestead, in Dade County, and separate the great saw-grass swamp of the Everglades from the fringe of mangrove swamps and salt prairie along the western shore of Biscayne Bay. This rocky country forms part of the Biscayne pineland. The area of these outcrops is a matter of conjecture. The relations of rock ridge and prairie along the western edge of the pineland are extremely intricate; the elevation of the outcrops falls gradually to the level of the Everglades and the pineland tapers off in a series of rocky keys or islands, of which Long Key is the largest, extending fully fifteen miles beyond the southwest corner of the main body of the pineland. To the north the outcrops are mantled by sand before the elevation of the rock surface has become as low as six feet above mean tide. The area is estimated at 200 square miles. North of New River, between the sea and the Everglades, except for the coquina near the beaches, outcrops of rock are few and scattered. In the Everglades some of the keys have a rocky foundation, such being reported nearly to Lake Okeechobee, but so far as known the only ones to form bare rock ridges are Long Key and those related to it, none of which reaches as far north as the parallel of Miami.

On the west coast of southern Florida hard rock outcrops are more scattered than on the east, but cover a wider area. Throughout the region of pine island and cypress strands, limestone projects here and there through the sands and is found along the roads from Fort Myers to Fort Shackelford and from Fort Myers past Immokalee to the head of Allens River. There are, moreover, areas of bare rock, extending as narrow, interrupted strips of varying length up to several miles, running through the pinelands.

A peculiar feature of the rock outcrops of southern Florida is the erosion of the surface. On the west coast, where the limestones are denser and finer than on the east coast, the rocks weather irregularly into rounded knobs and lumps a few inches to a foot above the general level of the surrounding sands, making it difficult to drive a wagon across bare expanses. In the rocky area of the east coast, the softer oolitic limestone weathers into angular shapes, the rock surface is extremely rough and walking is a task that requires constant watchfulness. The ground is strewn with loose, sharply angular fragments, products of weathering and the disruptive power of tree roots, and fixed angular masses a foot or so high with irregularly pointed summits and jagged outlines vaguely suggest miniature pagodas.

With this surficial erosion there has been solution underground. Next to the bristling rock surface, the most striking feature of the Biscayne pineland south of Miami is the presence of innumerable holes and hollows. The holes, which communicate with underground solution channels, are of all sizes, varying from those not over an inch across to those twenty feet or more in diameter. Their depths ranged from three to over ten feet. Besides the sharply outlined holes, there are throughout the pineland countless shallow hollows one to three feet deep and ten to one hundred feet across. A few of these hollows may owe their origin to original conditions of deposition, some may be due to the overturning of trees and consequent upheaval of the rocks loosened by roots, while others have been caused by the falling in of the roofs of subterranean water courses. Few of the holes and hollows are large enough to be termed sinks. The large vertically-walled holes running down to permanent water level form natural wells, the shallow hollows are best denominated potholes. The writer has heard of only one rock-rimmed opening in southern Florida that resembles the great sinks in the country to the north. That is Deep Lake, near the west coast, twelve miles east of Everglade postoffice. The lake, about four acres in extent, has a nearly circular shore line and no surface outlet; its reported greatest depth is ninety feet, fully seventy feet below sea level.

While there is danger of exaggerating the activity of underground and surface water in eating away the soft limestone of the east coast, yet there is plentiful evidence of solution. The potholes and the hollow-sounding areas of rock, perhaps twenty-five feet across, with as many as six or seven holes a foot or so in diameter showing the water beneath, that are found along the edges of the southern Everglades, the springs below tide level at Cocoanut Grove, and other points on the shore of Biscayne Bay, the Punch Bowl, a spring basin, the deep holes in New River, and the shallow gorge of Arch Creek with its low rock bridge all bear witness to the work being done.

SWAMPS.

As before stated the swamp land of southern Florida includes the great saw-grass morass of the Everglades, the cypress swamps and strands around its edges or intermingled with the pineland and the salt meadows and mangrove swamps of the coast. The very slight differences in elevation over long stretches of the mainland, the gradual slope of the rock surface below tide water level, the rock ridges on the southeast, the configuration of the upper surface of the bed rock and the rapid growth of grasses and sedges, are all factors in the distribution of land which is permanently wet and that which is, for a part of every year, dry.

EVERGLADES.

It is difficult for a person who has not seen the Everglades to form an approximately exact idea of that far-extending expanse of sedges, with its stretches of shallow water, its scattered clumps of bushes and its many islands. Photographs fail to convey the impressions of distance, of remoteness, and of virgin wildness which strike the visitor who looks out across that expanse for the first time.

The Everglades occupy the greater portion of southern Florida. They reach from Lake Okeechobee on the north to the vicinity of Whitewater Bay on the south and may have a maximum width of fifty miles. Their exact extent is undetermined as they have not been surveyed but is estimated at 5,000 square miles. The relief of the drier land is slight and the actual dividing line between saw-grass morass and cypress swamp, prairie, pineland or coastal swamp is extremely intricate. A difference of two feet in water level means the difference between shallow lake and dry land for hundreds of square miles. Hence, the relation between land and water shown on a particular map is not necessarily to be taken as absolute or even general; it may show in an approximate way the relations as determined in the month or months and year of the survey.

On the north the main body of the Everglades reaches to the southern and southwestern sides of Lake Okeechobee. Arms extend farther north but much of the eastern and most of the northern shore of the lake is bordered by cypress swamps, some of these containing the tallest and cleanest cypress to be found in Florida.

East of the Lake the Everglades fade away irregularly in the Allapattah flats, a region largely under water, at the end of each rainy season, where are interwinding strips of saw-grass swamp and grassy prairies, occasional patches of cypress and, more rarely, a hammock of hard wood growing on a slight rise in the almost dead level of the surface. Farther south the Everglades are bordered by prairie and cypress swamps, and at a few places reach nearly to the coast. The line of rocky pineclad islands that extends southwestward from the main body of the Biscayne pineland nearly to Whitewater Bay has a fringe of prairie, but there is a saw-grass strait east of the islands, and to the south are wide expanses of saw-grass, dotted with keys, that disappear seaward among thickets of dwarf cypress or mangrove. On the west the Everglades from Whitewater Bay to Lostmans River reach to the mangrove swamps that fringe the coast. North of Lostmans River an arm of the Everglades that runs up between the mangrove swamp and the prairie bordering the pine islands gradually disappears before getting as far as Allens River. Cypress swamp and prairie form the western boundary of the main body of the Everglades from Lostmans River to Caloosahatchee River.

The differences of elevation are slight, the islands are rarely more than two feet above high water level, and the slopes are so gentle as to be perceived only through the movement of the water or by levelling. The general slope south, in spite of the water seen everywhere in the rainy season, is not uniform. There are low, irregular rises to be measured by inches that serve to diversify the distribution of water and sedge-covered peat in the dry months of the year. There are also sloughs, narrow, winding strips of open water through the sedge, some of which extend for miles. Often it is not possible to detect a persistent current in these passages, which, for the most part, seem to have a north and south direction along the west side of the Everglades and a north-northwest and south-southeast direction toward the eastern side.

The water brought down by Kissimmee River escapes from Lake Okeechobee by the canal connecting with the Caloosahatchee and through the saw-grass. The short streams around the southern edge of the Lake shown on most maps of Florida do not flow into the Lake, but from it. They close up within a few miles and the thick growth of saw-grass makes the movement of water in any given direction very slow. Some of the water entering the Lake reaches the Gulf and some the Atlantic, the water moving as a mass slowly southward. The Lake is said to overflow into the Everglades along its whole southern border, when its waters rise to about 22 feet above mean sea level.

As evidence of the flatness of the Everglades, residents of the east coast state that when the canal leading from the Lake was dammed at Lake Hicpochee some five years ago, thereby raising the level of the water above the dam 3 feet, more water came down the east coast rivers as far south as New River, and the marginal prairies were under water so late in the fall as to hinder seriously the growing of vegetables. Whether the dam caused all the damage complained of is doubtful.

Elevation of the Everglades:—Since Lake Okeechobee overflows to the south and the waters escaping from it may reach either the Atlantic or the Gulf, the elevation of its surface is in a way a measure of the elevation of the Everglades. Various determinations of its level have been made by government engineers and surveyors. An elevation of 20.4 feet was found by a party of engineers in April, 1901, but an even lower level 19.8 feet is reported to have been found in March, 1908. High water levels, that have been published by the United States Engineer's office, are 22.4 feet in 1886, and 23.4 feet in 1878. Comparatively few determinations of elevation at points along the edges of the 'Glades have been reported. Some determinations along the eastern margin are: West of Lantana, 18 feet; west of Hillsboro Inlet, 14 feet; west of Fort Lauderdale, 17 feet; at the pool at the head of

Miami River, 6.2 feet. South of the Biscayne pineland and Long Key the height of the Everglades is less than 6 feet.

Willoughby in his trip across the 'Glades from Harney River to Miami River found that the water on the west side of the 'Glades had a slow movement southwest—and on the east side southeast. Ingraham, who crossed the 'Glades from Fort Shackelford to Miami found a southerly movement of water in a creek connecting Okaloakoochee Slough and the Big Cypress, but there was little current in the sloughs.

W. J. Krome, who made a careful survey of the southern 'Glades for the Florida East Coast Railway, found a slight southerly current in the slough between the mainland and Long Key, that forms the headwaters of Taylors River. The writer, however, found no perceptible current in this slough in June, 1908.

Evidently at times of highwater there is a perceptible movement of the Everglades water down the slight slopes toward the nearest outlets. At times of extremely low water the sloughs may be so separated that except in the immediate vicinity of a river no current is perceptible.

The normal difference between high and low water in the 'Glades is about two feet, the maximum difference may be twice as great. In the spring of 1908, it was possible to travel by wagon from the Biscayne pineland to and about Long Key, whereas in the late fall of 1906, one could cross the southern Everglades in a power boat.

Bed Rock Surface of the Everglades:—The Everglades have been variously called a lake in a rock-rimmed basin, and a vast sink. In the light of the facts accumulated by surveys of the War Department, the Disston Company, the Florida East Coast Railway, and the State of Florida, and by the explorations of Ingraham, Willoughby, and others, such designations as the above appear inexact, in spite of the aptness of the Seminole name "grassy water" during the late summer and early fall.

It is true that bed rock lies at or near the surface toward the edges of the Everglades. Along the east side from Jupiter River to Hillsboro River, the outcrops are few. South of New River, they are more numerous, and from just north of Miami to Homestead, the rock forms bare ridges with a maximum elevation of fifteen feet above mean water level in the Everglades. This series of ridges bends at its southern end to the west and gradually disappears as a series of rocky keys running west and southwest and reaching nearly to White Water Bay. South of this rock ridge from Cutler on Biscayne Bay around the southern end of the mainland, past Cape Sable, White Water Bay, Ponce de Leon Bay and the Ten Thousand Islands, there are no outcrops of bed rock above the sea level; nor are there any along the shore south of Sanibel Island. On the southwestern side of the Everglades rock comes within a foot of low water level in Rock Creek, an arm of one of the series of bays that together make up much of the lower twelve miles of Lostmans River. Three miles northeast of this point, rock outcrops in a pine island. Thence northward there are many rock exposures scattered through the flat lands. They can be seen at the head of Allens River and eleven miles to the east on the property of the Deep Lake Fruit Company. The belt of country in which rock is exposed widens northward and at Naples is fully forty miles wide from east to west. This region is monotonously level and the rise of the rock surface inland is slight. In short, bed rock outcrops around the main body of the Everglades from Jupiter River to Fort Shackelford with no important interruption except between Lostmans River and the farthest west of the rocky keys beyond Long Key. In this break, rock does not, on the average, lie more than three feet below the level of low water.

Making allowance for the general slope of the water level towards the drainage channels on the east and west coasts, this hydraulic gradient amounting to three-tenths of a foot per mile for thirty miles northwest of Miami, it is evident that the actual depth to bed rock in the middle of the Everglades is three or four feet more than what would be shown by measuring below a level line extending from rock rim to rock rim. As these points might be forty miles apart, and as the depth below the line at the latitude of Miami would be on the average less than five feet, the inappropriateness of the term basin for the southern portion of the Everglades is evident.

The term sink is not accurate because the area is too large; the rock floor too flat. Potholes and small sinks are common in the rocky prairie south and southeast of the main body of the Everglades, and there may be large sinks filled with mud in their main body but the existence of such is not proven. It is possible also that there may be sinks of some size between the line of rocky keys and the north shore of the Bay of Florida. Certain features of the lakes back of Flamingo suggest that they are sinks.

While the rock floor of the southern Everglades is known to be almost flat, yet it is altogether possible that farther north there are true basins of considerable extent. The preliminary surveys made for the drainage work undertaken at New River by the Florida Drainage Commission have shown that the bed rock slopes off to the westward more steeply there than to the south, and the depth to bed rock five miles west of the eastern rim back of Fort Lauderdale is probably not less than twenty feet. Surveys to the north seem to indicate a flatter slope to the bed rock and there is a report of an east-west rock ridge within six feet of the surface between four and five miles south of the south end of Lake Okeechobee.[1] There is also known to be a rock ridge running north from Long Key, reaching as far north as Miami; hence, it is probable that the Everglades occupy a series of comparatively shallow rock hollows. Whether these hollows were as deep when the Everglades first occupied them, as they now are, that is, whether they have been deepened by solution through underground drainage, whether they represent original inequalities of deposition of the lime rock, or whether they are buried shallow valleys, can not be determined from the evidence at hand. It is probable, however, that the deepening and enlarging effect of underground solution has been exaggerated.

Bed rock lies five feet below low tide level at Jewfish Creek; eight feet at Flamingo; five to ten feet in Whitewater Bay; thirteen feet at the mouth of Shark River; thirteen feet at the mouth of Lostmans River; twelve feet on Chokoluskee Island and five to ten feet at Everglade.

Origin of Everglades:—The Everglades owe their existence primarily to an abundant rainfall and to the slight elevation of southern Florida. Even were there no basin-like structure whatever, and were the bed rock surface absolutely flat along an east-west line, the present rainfall, the sluggish drainage, and the luxuriant growth of vegetation would result in a swamp forming on the center of the peninsula from Lake Okeechobee. In short, the Everglades resemble in origin the Dismal Swamps of North Carolina and Virginia.

The peat found throughout the large part of the Everglades rests on rock, sand or marl. In places soundings indicate more than one peat bed, with sand between. The relations of peat and sand to bed rock west of Fort Lauderdale are shown by the following generalized section along the drainage canal there; the section is based on data furnished by J. H. Newman, engineer.

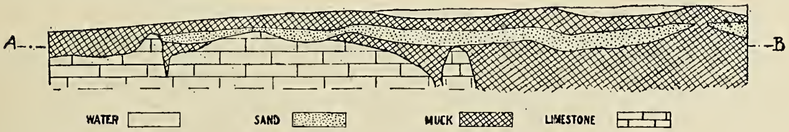


Figure 3.—Section of Everglades west of Fort Lauderdale.

CYPRESS SWAMPS.

Most of the many tracts of cypress scattered over southern Florida call for no especial notice. Probably the finest cypress grows northeast of Lake Okeechobee. The largest tracts of good timber are west of the Everglades; Okaloocoochee slough and the Big Cypress are the two most important. Both have extremely irregular outlines with numerous arms forming strands among adjacent pine islands or prairies. The southern boundary of the Big Cypress is not indicated on most maps of southern Florida and in many the extent of the swamp is greatly exaggerated, the name being printed across a region where cypress swamps, prairies, hammocks, and pine islands are intermingled. During high water, boats can pass through the Big Cypress from the Everglades to the Gulf north of Cape Romano. The maximum east-west width of the swamp may be forty miles. Ten miles east of the head of Henderson's Creek is a cypress swamp six miles wide, and east of Everglade is another swamp six to twelve miles wide, these swamps being connected with other swamps that form arms of the Big Cypress.

---

[1] R. E. Rose, State Chemist, in a note to the writer says no such rock ridge was found by the South Canal surveys, and near the south shore of Lake Okeechobee rock is over ten feet below surface. Twenty miles south of the lake rock was found at six feet.

COASTAL SWAMPS.

As a consequence of the low relief and the gradual slope of the land below sea level, southern Florida has wide areas of coastal swamp. These areas include the wet lands along the lagoons or "rivers" lying back of the barrier beaches of the east coast, a part of which is open marsh, a part has a scrubby growth of mangrove, and the more extensive swamps of the south and southwest coast, which die away in a network of channels and islands.

On the west coast, these mangrove-covered islands, and the mangrove swamps behind them, extend from Whitewater Bay, the southernmost arm of which is separated from the Bay of Florida by less than five miles of wet prairie and swamp, to Cape Romano. North of Marco the coastal islands and the swamp land include pine islands and in places pines grow to the Gulf shore.

The red mangrove most frequently grows as a bushy tree, under twenty feet high. The swamp that forms the southern fringe of the mainland from Chi's Cut to six miles east of Flamingo has such low trees, as have the many islands in Whitewater Bay and most of the patches of swamp along the main line of the Florida Keys from Biscayne Bay to the Marquesas. But in the Shark River archipelago and the southern portion of that unmapped maze of land and water, the Ten Thousand Islands, the mangrove forms a noble forest, the trees growing to a height of 60 feet or over with clean, smooth trunks 2 feet or more in diameter at the butt and without a limb for 30 feet from the ground. They rise from the Gulf like a green wall and are one of the most striking features of the shore lines of southern Florida. The majestic appearance of these trees compared with the look of those in Whitewater Bay can not be explained by any local peculiarity of climate. Rather it is probably the result of the aeration of the thick bed of soft gray marl on which they grow by the swing of the tides, which here have greater amplitude than anywhere else on the whole coast of the peninsula, fully five feet. Northward, toward Cape Romano, the trees become smaller and along the inlets back of Caximbas they are as bushy as in Whitewater Bay.

The maximum width of coastal swamp in southern Florida is unknown, since the boundary between coastal swamp and Everglades is a matter of conjecture. After a season of heavy rainfall the channels leading from the latter carry fresh water and after a dry season salt water. Thus in May, 1908, the writer found salt water in Lostmans River within the Everglades, seventeen miles from the mouth of the river, while in October of the same year, after the heavy rainfall of the summer and early fall the water was fresh several miles nearer the Gulf.

THE KEYS.

The keys or islands, that fringe the south Florida mainland differ widely in size, shape and surface features. Some are typical barrier beaches, long, narrow, low-lying banks of sand with cocoanut palms crowning the beach ridges, their inner faces hidden in mangrove swamps. Many are true mangrove islands, shoals formed by the efforts of tidal and wind-induced currents where mangroves were able to get a foothold and hold material thrown up by the waves. Others are sand banks so low lying or exposed as to support only a scanty growth of beach grasses and weeds, and still others, notably those in the main chain that extends from Virginia Key opposite Miami to Key West are of rock or have a rock foundation reaching to or above mean sea level and are covered with various scrubby hardwood trees, palms, and even pines.

Within this chain, fringing the mainland or dotted over the Bay of Florida are other keys, that can be seen in all stages of growth, from banks below sea level to banks just bare at low tide on which mangroves have got a foothold and by their entanglement of roots, are catching seaweed and drift wood, arresting the movement of sand and marl and actively pushing out the shore line.

Whitewater Bay, which lies behind the Cape Sable foreland and has an extreme northwest-southeast length of perhaps twenty miles, is full of these mangrove islands, the mangroves on the edges growing out of water two feet or so deep. North of Whitewater Bay, the Ten Thousand Islands form an intricate network of channels and of marl banks supporting a heavy growth of red and black mangrove. From Big Marco Pass to Sanibel Island an almost continuous beach of siliceous sand broken only by narrow inlets, such as Johns Pass, Gordons Pass, Big Hickory Pass and Big Carlos Pass, faces the Gulf. These passes lead to inner bays dotted with islands of varying size, but possessing few features of special interest.

THE FLORIDA REEF.

The shores of the main line of keys, extending from opposite Biscayne Bay to Key West and Boca Grande, in places are rocky, in others are bordered by wide flats of marl or calcareous sand. In places the surface of the keys is bare rock, in others it is sand or marl. Most of the keys have few wide strips of land attaining an elevation of as much as six feet above the highest spring tides.

The longest of the keys, Key Largo, has an extreme length of thirty miles, but is nowhere over three miles wide, and the maximum width of ground above the level of high spring tides is considerably less. Big Pine Key is ten miles long and has an area of high ground nearly two miles wide, with a greatest elevation of thirteen feet; while Key West is four miles long by one mile wide and the highest ground, which is near the center of the city of Key West, has an elevation of thirteen feet. The highest point in the whole chain of keys are two small knolls, one on Windley's Island, the other on Plantation Key, just to the north. The knoll on Windley's Island, now partly quarried for fills and ballast along the railway line to Knights Key, was eighteen feet high. That on Plantation Key was of about the same height.

A glance at a map of the Florida Keys shows that the islands are separated by Bahia Honda Channel into two distinctly differentiated divisions. East of the channel the islands are narrow and lie along a sweeping arc curved toward the southeast. Outside this arc is the Strait of Florida, inside are the Bay of Florida, Blackwater Sound, Card Sound and Biscayne Bay. The western end at Bahia Honda is 35 miles from East Cape on Cape Sable, the nearest point of the Florida mainland. The rock ridge of Key Largo is not two miles from the edge of the mangrove swamp that fringes the end of the peninsula and from there northward the keys are within eight miles of the mainland.

West of Bahia Honda the keys form an archipelago roughly triangular in outline. In this bunch of islands, the westward prolongation of the arc in which lie Bahia Honda and the keys to the east and northeast is found in the southern shore line of the keys, but instead of lying parallel to this arc the keys themselves have a prevailing north-northwest, south-southeast arrangement, perpendicular to the arc. The causes of this striking dissimilarity in position are twofold, a difference in rock structure and a difference in the direction of the forces which have shaped the islands.

Bahia Honda and the keys east of it represent an uplifted coral reef more or less covered with sand and marl, hence their basement rock ridges have the trend of the coral patches of the old reef. The foundation of the keys west of Bahia Honda is an oolitic limestone formed from deposits in a broad expanse of shallow water; hence there was no original ridge-like upbuilding, no pronounced trend to the rock structure. Variations in resistance to erosion have resulted in irregularities of the rock surface, which, as along the old reef to the east, has been more or less covered with marl and calcareous sand. The prevailing direction of the passages separating the keys is due to tidal currents, which owe their power to differences in time and height of the tides of the Gulf and the Strait of Florida.

The shaping of the great arc of the keys is the joint product of several factors. The old coral reef was built up from the bottom in water of a certain depth along a line that had the general direction of the southeastern and southern edge of the submarine plateau of the Florida peninsula. The curve of this edge had been in turn controlled more or less by the eastward flow of the Gulf Stream against the probable westerly movement of the prevailing winds.

The decided differences of surface, bare rock, or rock with a very thin veneer of leaf mold, sand, and marl, and the slight differences of elevation above high tide result in great differences of vegetation.

Near the water's edge and on flats or even rock beaches below high tide level grow mangroves, on the beach ridges cocoanut palms, not indigenous, flourish. Inland the low marl flats support grasses, sedges and a variety of salt-resistant weeds. The higher ground called hammock, supports a dense growth of scrubby hardwood trees, buttonwood, ironwood, madeira, etc., that seldom attain a height of more than twenty feet, while on three of the keys, No Name, Little Pine and Big Pine, notably the latter, are patches of pine.

The surface of the rock outcrops along the keys differs from that of most of the bare rock in the Biscayne pineland or in the flat lands of the west coast between the Everglades and Cape Romano. It is less weathered, hence more even and, except on beach slopes worn by spray, has not a jagged appearance. Angular blocks, disrupted by tree roots or by temperature changes are scattered over it, but in places it is quite smooth over areas of twenty to one hundred square yards. Holes and hollows resembling those found in the Biscayne pineland and formed in the same way, abound, but the rock surface has a look of newness, its major inequalities are not the result of subaerial decay. It is like that of some of the low keys in the Everglades to the west of Long Key.

Since the keys were elevated to their present height, they have been subjected to forces that tend to advance the shore line and to those that tend to push it back, and the easterly winds have played an important part in giving the southern faces of the keys their present trend and outlines. Differences in time and height of tides in Florida Strait and the Bay of Florida, together with the area of the bay, result in strong currents sweeping through the passages between the keys, particularly the openings west of Long Key. When northers blow, the shallow waters of the Bay are milk white over large areas from the limy stuff in suspension. This is deposited, to be picked up with a change of wind or tide, or is carried to sea in such quantities as to show in the blue waters of the Gulf Stream ten miles outside the keys. The bars and banks about the keys and in the Bay of Florida, the areas of marl and calcareous sand above sea level show the activity of waves and currents and indicate how much material they have recently handled.

SHORE LINE TOPOGRAPHY.

The shaping of the shore lines of any region is the joint work of tidal and wind-made currents, waves and winds. The share of each of these agencies is determined by the efficiency permitted through antecedent conditions of coastal topography, the character of the shore line materials, and the circumstances controlling the general circulation of ocean currents and winds, and the work being done at any given time is in a measure controlled by the rise or fall of the land with reference to tide level. Thus shore line features have the aspects of infancy, adolescence, or maturity according to the length of time the waves and currents have been working at a certain level and the effectiveness of their attack on the land. In the same region, as in southern Florida, adolescent features may be found where the attack is strong and infantile where attack is weak or ineffective.

The south Florida mainland is low, its coasts dip gently beneath the water, the shore line materials are nearly everywhere unconsolidated. Under these conditions slight changes of level can swing shore lines over long distances, and the effectiveness of wave attack is easily modified by agencies which tend to build up land, such as corals, or to push out the shore, such as mangroves.

The region has no well-marked valleys, no large rivers, hence antecedent drainage has been of minor importance in determining the work of waves and currents. Also the streams are clear, they bring down little matter in suspension, their waters are not heavily mineralized and they contribute comparatively little to the sea bottom, hence delta building by streams is insignificant. At the same time an immense amount of limy material is supplied by the remains of marine organisms, the agitation of the shallow near-shore water facilitates deposition of calcium carbonate, and the effluent swamp waters contain organic compounds that may act as precipitants. Hence banks of marl form near river entrances or outsides of passages leading from lagoons, and where the banks are protected mangroves gain a foothold and interrupt the sequence of forms that would result from the unopposed action of waves and currents.

Maps of the east coast show a shore line with adolescent features, such as cuspate forelands, well developed bay bars and long beaches with gentle curves. The offsets and overlaps of the bars and beaches show that the movement of sand is toward the south. This movement is very marked at Jupiter Inlet. When the bay bar at the mouth of the Inlet is cut through at its north end to make a navigable channel, the drift of the sands makes the channel travel southward, till as it approaches the south side of the Inlet it shoals up and the water flows over the bar in a shallow sheet.

The lagoons or "rivers" of salt or brackish water back of the beaches are being filled by swamp growths. While the tidal swing is small, the extent of the lagoons, and the amount of water discharged at each ebb is sufficient to transport and assort lighter debris, but in the shaping of the coast the waves and along shore currents play the chief part.

In the Bay of Florida the rocky shores of the coral islands show the nip of the sea, while banks and marl flats are gaining areas, and mangroves vigorously extend the land. Tidal currents are the principal agencies of transportation along the south side of the bay, where under favoring conditions currents with velocities as high as five miles an hour rush through the openings between the keys. Along the north side of the bay tidal action is much weaker and winds and currents perform a proportionately larger part of the work. Wave action though of importance, is limited by the shallowness of the bay.

From East Cape to North Cape extends a strip of shell sands, the Cape Sable foreland, that has been pushed up from the bottom by the waves. Tidal action is strong, there is a pronounced tide rip past Middle Cape, but no dominant along shore movement of sand north or south. From North Cape to Cape Romano are few stretches of beach, mangroves grow out of the water of the Gulf, the shore line is extremely intricate. Tidal scour is strong at the inlets leading into White Water Bay, but to the north most of the entrances are obstructed by bars. From Cape Romano to the mouth of Caloosahatchee River the shore line topography approaches that of the east coast. Long beaches of sand, spits, bay bars denote adolescence. The predominant movement of sand along shore, as shown by offsets and overlaps, is southward. This indicated southward drift is probably due to the effectiveness of the winds from the west and northwest rather than to a prevailing easterly movement of air currents. The great seas of hurricanes and northers are of chief importance in distributing and piling up the sand.

WASTE AND GROWTH OF THE MAINLAND AND KEYS.

The salient features of the shore line topography of southern Florida have been summarized, as a detailed relation of the reactions that have determined the present outlines of the coast and all the varied aspects of the land mass and of the keys lies without the province of this paper. But there are features of the growth and waste of the land which, as they have been noticed in most descriptions of the topography and geology of southern Florida, are here discussed briefly.

Waste by Solution and Erosion:—The limestones are, as a rule, soft and porous. In addition, they are remarkably free from aluminous material; hence, they are easily disrupted by tree roots, readily dissolved by percolating surface water charged with CO_2 and eroded without difficulty by waves and streams. The effects of solution are everywhere visible in the outcrops of oolite and coral rock; the pot holes, natural wells and springs show how active has been the work of underground water. The jagged surface of the Miami oolite (described on p. 187), and the bareness of its ridges show how easily it dissolves and how free the original sediments were from clay.

Along the coast, wherever rocks reach the water edge, the waves are eating them away. Tidal and wind-made currents carry off part of the waste in solution and part in suspension, while the coarser detritus is distributed as sand.

Growth of the Land:—Besides the currents and waves which assort, distribute, and pile up the waste of the land, organic agencies play an important part in extending the shore lines. In fact, such agencies are of greater importance in south Florida than in any other part of the United States, for here are coral polyps building up rock-like ledges strong enough to stand, for a while at least, the hammer of the breakers, and mangroves arresting and holding finely-divided material that has been swept about by currents. In addition, thick beds of oyster shells form banks, hard masses of "worm rock," the limy tubes secreted by a mollusk, protect and extend shore lines, and in addition, and perhaps most important of all, the remains of the teeming vegetable and animal life of the salt water contribute in the aggregate an immense amount of material to the upbuilding of the land.

To the interplay of the agencies of waste and growth above described are due those peculiar features of the shore line topography of southern Florida which have been noticed on a previous page. The special significance of those features in this connection is that the agencies which wear away the land and those that extend it have not, in most accounts of the geology of the region under discussion, been sharply discriminated, or one group has been given undue importance in comparison with the other.

As an instance may be cited the southern growth of the mainland and the character of the mangrove islands along the northern part of the Bay of Florida and in Blackwater and Card Sounds. The bed rock floor of limestone that outcrops in the Biscayne pineland, on Long Key, and adjoining keys in the Everglades, slopes gently to the south. On it the marls, sandy beaches of Cape Sable and below the prairie back of Flamingo, those of the mangrove swamp to the east and of the mangrove islands in the bay, now rest. Hence, these islands and the projecting tongues of swamp along Blackwater Sound can hardly be erosion remnants of a former continuous land surface. Rather do they represent the work of agencies, which, if unchecked by a depression of the coast, will ultimately join the mainland to the keys.

EVIDENCES OF RECENT CHANGES OF LEVEL.

While the accumulated evidence shows that the Pleistocence and Recent history of Florida has been marked by no great disturbances, that the elevations or depressions of the land, though affecting great areas have been of relatively small amount, and while there is no reason to suppose that the region will be violently disturbed in the immediate future, yet as the question of relative permanency of height of land is of importance because slight changes with respect to sea level will have a pronounced effect on the habitability of the coasts, the evidence available is briefly summarized.

That the coast line has been elevated the old coral reef of the Florida keys is abundant proof. That it has been slightly depressed since the maximum elevation is indicated by solution cavities in the limestones extending considerably below water level and by the relation of the dunes to present shore lines.

As to more recent changes and the present movement we have the evidence of swamps, of shore lines and of human records.

If the swamps are being depressed there should be tree trunks of the older forests buried beneath the sediments that have accumulated since the trees fell. The writer noted a thick stump in gray marl at one of the numerous entrances to Shark River, near the plant of the Minetto Lumber Company. It was about three feet below the present surface of an islet, which is covered by water at high tide. The evidence was not conclusive, as the log might have drifted to its resting place. Still the present growth of the swamps favors a recent depression.

The testimony of the shore lines is contradictory. Possibly the best evidence is that of the series of low beach ridges extending from East Cape to North Cape on Cape Sable. This strip of foreland having a steep beach of coarse shell sand facing the Gulf and falling off inland to a mangrove swamp flooded at spring tides, seems to show that there has been a slight sinking of the coast since waves started to heap up the sand.

The human records to which appeal can be made are the numerous indian mounds, or kitchen middens, composed chiefly of oyster shells, found at many places along the coast. Some of the mounds are of great size, notably the accumulation of shells on Chokoluskee Island which covers over fifty acres to an average depth of seven feet. Since the mounds stand in swamps the relation of the bottom layers of shells to present sea level and to the deposition of marl and vegetable matter in the surrounding swamps should be an index of any coastal rise or fall. An examination of mounds at Jupiter Inlet, in and near Chokoluskee Bay and at Marco, however, gave less data than was anticipated. In places creek channels have cut into the mounds, in places wells have been sunk through them, consequently sections showing relations of the lowest layers of shells to sea level and to the underlying materials are not hard to find. Around the edge of the mounds there has been some burying of shells by wash, but the bottom layers rest on swamps and if the first Indian dwellings stood on posts in ground flooded at high tide, there is no sign of a measureable sinking of the coast since the time when the building of the mounds began.

Thus the evidence at hand shows that the coast of this part of Florida is not now rising, but is stationary or sinking. If it is sinking, then the rate of depression is so slow that it can not be determined from human records which must long antedate the discovery of America.

GEOLOGY.

GENERAL STATEMENT.

The general geologic structure of the Florida peninsula, the character of the materials which underlie the surface, their areal distribution, relative position and age have already been discussed,[1] and will not be reviewed here, but as the topography of southern Florida, as a whole, is different from that of the central and northern parts of the State, so the geology has features which differentiate the region from the greater portion of the peninsula.

---

[1] Pp. 46 to 164 of this report.

The anticlinal structure plainly shown to the north by the distribution and order of the sedimentary beds that underlie the surface sands is not evident in southern Florida though it is possible that an examination of the outcrops in the pinelands south of Caloosahatchee River may show that a broad, low anticline can be traced as far as the Big Cypress.

So far as is now known, however, the rocks that show at the surface throughout the south end of the peninsula lie almost flat. Cross bedding with dips as high as thirty degrees may be seen in places and an apparent stratification of lesser dips but greater extent is not uncommon, but in general no well marked evidence of regional folding is to be had from a study of rock exposures.

Since the beds lie flat and their elevation above sea level is nowhere more than thirty-five feet and over most of the region less than fifteen feet, it is evident that a thin formation may cover a great extent of country and that any tilting or folding of unexposed beds must be inferred from what has been determined to the north or established through the comparison of carefully kept records of deep borings.

Except for a possible extension of Pliocene beds south of the exposures on Caloosahatchee River previously described by Matson and Clapp (p. 123), all the surficial formation of southern Florida, unconsolidated and consolidated, are of Quaternary age and include those laid down in Recent and in Pleistocene time.

PRE-PLEISTOCENE FORMATIONS.

General Statement:—The outcrops of Oligocene, Miocene, and Pliocene beds in central and northern Florida and the relations of the beds have been discussed by Matson and Clapp (pp. 50 to 145). Neither Oligocene nor Miocene formations come to the surface in southern Florida and outcrops of Pliocene deposits are not known. Hence the character, thickness and relations of any beds older than Pleistocene may be inferred from what has been determined to the north or proved by samples collected from a number of scattered wells. But the nearest outcrops of Miocene and Oligocene beds are so far from the greater part of the area under discussion that inference as to the character, thickness and depth of Miocene or older beds are little better than guesses, and, unfortunately, reliable records of deep wells are few. Still, enough is known of the deeper lying beds to permit the drawing of general conclusions as to the character and origin of the Miocene and Pliocene deposits.

Evidence of Well Records:—On the east coast the list of localities where there are wells over 100 feet deep comprises Gomez, 1200 feet;

Hobe Sound, 1100 feet; West Jupiter, 101 feet; Palm Beach, 1212 feet; Fort Lauderdale, 108 feet, and 387 feet; Delray, 119 feet. Along the line of the keys deep wells have been sunk at Indian Key Channel over 650 feet; Key Vaca, 700 feet; Knights Key, over 700 feet; Big Pine Key, over 700 feet; Key West, 500, 950 and 2398 feet. While on the west coast there are wells at Marco, 376 feet; Estero, 285 feet; Punta Rassa, 140 and 280 feet; St. James City, 148 and 335 feet; Sanibel Island 420 feet, and over 600 feet, and Buck Key, 605 feet. In addition wells have been sunk in the prairies south of Caloosahatchee River and west of Lake Okeechobee as follows: T. 47, R. 31, 647 and 691 feet; T. 48, R. 31, 720 feet; T. 46, R. 33, 921 feet.

The logs of most of the wells mentioned were not recorded carefully and logs of several are not available. More or less continuous series of samples were saved at Palm Beach, Indian Key Channel, Key Vaca, Key West, and Buck Key.

Palm Beach:—Darton[1] gives the following partial record for the Palm Beach well:

Partial record of well of C. I. Craigin, Palm Beach.

	Feet.
Sands with thin layers of semi-vitrified sand at 50 and 60 feet	0- 400
Very fine grained soft, greenish gray quartz sand, containing occasional foraminifera and water worn shell fragments	400- 800
White sand with abundant foraminifera of four or five species	850- 860
Gray sand containing shark's teeth, small water-worn shells and bone fragments, sea urchin spines, and lithified sand fragments	904- 915
Samples at frequent intervals, Vicksburg limestone containing Orbitoides in abundance throughout, together with occasional indeterminable fragments of molluscan casts, corals and echinoderms. It is a creamy white, hard, homogeneous limestone throughout	1000-1212

Darton was unable to determine definitely the age of the series overlying the limestones, but the organic remains from 800 to 915 feet suggested Miocene age, while foraminifera between 400 and 800 feet indicated that the beds whence they came are also probably of Miocene age.

This record shows that the top of the Vicksburg group (Lower Oligocene), lies between 915 and 1000 feet below the surface at Palm Beach. The great thickness of quartz sands is the most noteworthy feature of the record.

Key Vaca:—Two wells were sunk at Marathon, Key Vaca, one reaching a depth of 435 feet, the other 700 feet. The combined records of the two wells gives the following section.

---

[1] Darton, N. H. Am. Jour. Sci., (3) xli, pp. 105-106.

Record of wells of Florida East Coast Railway, Marathon.

	Feet.
Reef rock	0-105
Hard to soft white limestone, with much white marl	105-148
Soft white limestone with shell casts	148-150
Medium hard white limestone, shell casts and shell fragments	150-155
Soft white limestone with quartz grains, proportion of quartz increasing with depth, shell fragments and casts	155-176
Medium fine white quartz-sand containing numerous irregular nodules, with yellowish marly sand at 210 to 215 feet	176-230
Quartz sand in a varying proportion of limy mud, sand grains, colorless mud, yellowish to dark green; streaks and beds of friable sandstone containing shell casts; bed of oyster shells at 240 feet	230-300
Quartz sands or beds of soft friable sandstone containing shell casts; streaks of dark green limy clay, 306-310 ft.; beds of shells, few determinable fossils, probably Miocene, 378-390	300-400
Quartz sands as below 230 feet; beds of soft friable sandstone with shell casts; gravel bed with much worn pebbles up to 40 mm. long; tough green limy clay, at 407 to 410 feet	400-435
Quartz sands with little sandstone, tough dark clay in occasional streaks	435-700

While the many samples of drillings from this well show the lithology of the formations penetrated, they give much less satisfactory evidence as to geologic age. The sands below 176 feet yielded but a small variety of determinable fossils. An occasional claw or carapace of a small crab or a few barnacle plates were the only organic remains noted in going through many feet of sand. The friable sandstones contained many casts, internal and external of pelecypod shells, the external casts being of sandstone, the internal of more clayey material. These casts while numerous, were not sharp enough to be of diagnostic value.

The shell beds yielded a small variety of species. T. Wayland Vaughan identified five species including pectens and an oyster which were probably Miocene from collections between 375 and 420 feet.

Thus the Key Vaca section, while it shows limestone, Pleistocene, and sands probably Pliocene, gives no data for separating Pliocene from Miocene. The coarseness of the sands, their barrenness and the character of the few determinable fossils between 176 and 400 feet indicate shoal water and strong currents. No break in deposition is determinable.

Key West:—Samples collected at 25-foot intervals from the deep well at Key West were examined by E. O. Hovey. The following generalized log is from his detailed description of the samples down to 2000 feet.

Record of well at Key West.	*Feet.*
Yellowish oolite	0- 25
White yellowish or light gray limestone, with oolitic lumps	50-175
Fine white lime-sand rock	175-200
White porous oolitic and sandy limestone	200-275
White more or less solid limestone	300-375
Friable soft gray lime-sand rock	400-675
Yellowish to brownish lime-sand rock, *Orbitoides,* 800-850 feet	700-1075
Light gray, partly dense and partly porous limestone	1100-1175
Gray lime-sand rock	1200-1350
Yellowish gray lime-sand rock, with some porous limestone	1375-1450
Lime-sand rock varying in color and compactness, with strata of dense limestone	1475-1975
Yellowish to light brownish gray limestone, rather solid, with porous portions	1975-2000

The most noteworthy feature of this log is the absence of beds of quartz sand, though such beds have a total thickness of over 400 feet at Key Vaca, and over 200 feet at Big Pine Key, which are respectively forty miles and twenty-five miles east of Key West. Certain peculiarities of the samples described by Hovey, notably the abundance of oolitic material at various depths, taken with the reported incomplete casing of the well throw doubt on the value of the record, but probably no considerable bed of quartz sand was penetrated.

The general aspect of the organic remains, bits of molluscan shells, corals, foraminifera, echinoids and coralline algae, led Hovey to believe that the rocks originally were shoal water deposits. The samples show that during Miocene and Pliocene time as during Pleistocene and Recent time, much quartz sand did not get as far south and west as Key West. Hovey thought the Pleistocene beds at Key West might be less than fifty feet thick, but was unable to separate Pliocene and Miocene. The top of the Vicksburg group he placed at 700 feet, thus making the total thickness of the Pliocene and Miocene less than 675 feet.

Buck Key:—A record of the Buck Key well given from memory by the driller, James Sykes, of Fort Myers, supplemented by samples saved at odd depths, furnishes the following section:

Record of well of W. H. Knowles, Buck Key.	*Feet.*
Sand and shells	0- 50
Brown crystalline limestone with cherty streaks and sand grains	50- 60
White quartz sand, with marl and shell fragments	60- 63
Brownish sandy limestone with shell fragments	63- 65
Dark greenish marl	65-145
White quartz sand, with shell bed at 150 feet	145-275
Medium dark greenish marly sand, with shell beds, and streaks of lighter marl	275-490
White to brownish and soft to hard limestone, with a few shell casts, hard brownish limestone contains many siliceous grains	490-605

OLIGOCENE.

Foraminifera of the genus *Orbitoides* that characterize the Vicksburg group were found in drillings from the wells at Palm Beach and Key West. The top of the limestone may lie about 950 feet below the surface at Palm Beach and 700 feet below at Key West. An eastward dip of the limestone is indicated by the records of wells east of Fort Myers, but evidence to show the amount of dip is meager. A southern prolongation of the anticlinal fold of west central Florida is probable, but can not be established from the known data.

Thickness:—Samples from the Palm Beach well showed *Orbitoides* for 312 feet, samples from the Key West well showed the same fossils for 1100 feet. It is fairly certain that the Key West well was not cased to below 1000 feet; hence little reliance can be placed on the samples from 1000 to 2000 feet, so carefully examined and described by Hovey. Thus there is no evidence to establish the thickness of the Vicksburg group there, though Hovey noted changes in the character of the limestones at 475 and 2000 feet. There is no evidence to establish the thickness of Oligocene beds above the Vicksburg group, which were probably penetrated over eighty feet at Indian Key Channel.

MIOCENE AND PLIOCENE.

Lithology:—A comparison of records from points so widely separated as Palm Beach, Key Vaca and Buck Key shows a surprising thickness of beds composed largely of quartz sand, and contradicts the old belief that the southern end of the peninsula rests on a solid limy foundation. Between the surficial limestones and the limestones of Upper Oligocene age are 200 to 700 feet of unconsolidated material that is siliceous, rather than calcareous. The succession of limy beds at Key West is explainable by remoteness from the mainland and consequently from the source of the quartz sands.

Thickness:—No deep well in southern Florida has proved definitely the thickness of Miocene and Pliocene sediments at a given point, and it is doubtful if any well that may be drilled will show Miocene deposits sharply separated from Pliocene, or if wells in most of the region will afford a basis for separating the Miocene from the upper beds of the Oligocene. Hence the total combined thickness of the Pliocene and Miocene beds is likely to remain conjectural. It may amount to 800 feet at Miami, and 516 feet at Indian Key Channel.

Source of Siliceous Material:—Some of the Miocene and Pliocene sands probably represent siliceous grains derived by weathering and erosion from the Upper Oligocene and Lower Oligocene limestones. Much more of it may have worked south along the east and west coast of the peninsula or around the shores of the islands that foreshadowed the peninsula. The quartz grains no doubt halted to form beds of sand, sandy marl and even sandy limestones many times in their journey from their original ledges to the south end of the peninsula. They were worked over again and again and even roughly concentrated in this southward drift, so that the mass of siliceous material at the south end of the peninsula represents the removal and assortment of many times its bulk of quartz-bearing rock. The process of concentration apparently continued through the Miocene and Pliocene periods, a sufficent length of time for the accumulation of hundreds of feet of sandy material. Only a depression of the coast, and the substitution of off-shore for near-shore deposits would interrupt the process. There is no evidence of such interruption in the sands under Key Vaca.

PLEISTOCENE.

UNEXPOSED PLEISTOCENE FORMATIONS.

Of Pleistocene formations earlier than the limestones and sands to be described, the only positive evidence at hand is that of well samples. A few records show a considerable thickness of Pleistocene material. Thus a bed of coquina at a depth of 118 feet in a well at Delray yielded twenty-four species of mollusks and two of corals (non-reef builders), of which ninety per cent. were identified as Recent by T. Wayland Vaughan, indicating that the age of the coquina was early Pleistocene, earlier than the Miami oolite. Few samples have been taken from other east coast wells between depths of 100 and 200 feet. Samples from the well on Key Vaca showed reef rock to 105 feet. At Key West limestones, evidently of shoal water origin, are indicated by the samples from the deep well, but the thickness of Pleistocene beds earlier than the surface oolite is uncertain. On the west coast rather fine quartz sand underlies the Lostmans River limestone at Everglade. This sand is at least forty feet thick. No samples were saved from the deep well at Marco and but few from the wells at the mouth of Caloosahatchee River. The latter, except the Buck Key well, show sands and marls to a depth of over 100 feet.

The notable feature of the well records is the reported finding of sands and unconsolidated material below hard rock at widely separated localities. Samples from West Palm Beach, fifty-five to seventy-five feet, show much worn shell fragments cemented, and replaced by crystalline calcite, with pockets or beds of quartz sand, but no hard rock close to surface. Samples from Miami show much the same variety of material below the surficial oolite.

EXPOSED PLEISTOCENE FORMATIONS.

The surficial deposits of Pleistocene age comprise limestones, coquina, and sands. The limestones form bare ridges and occur as inconspicuous scattered outcrops. The coquina lies along or back of many miles of ocean beach on the east coast and the sands mantle the surface of the greater part of the pineland.

The limestones described on the following pages are alike in being of marine origin, but non-marine limestones probably occur. Dall has mentioned the finding of hard ringing aeolian limestone on Corkscrew Creek, southeast of the mouth of Caloosahatchee River, and there is reason to believe that scattered deposits corresponding to the *Planorbis* rock of Dall will be found toward Lake Okeechobee or between Caloosahatchee River and the Big Cypress. In the localities visited by the writer, however, but one occurrence of a possibly non-marine limestone was noted, a soft loosely-compacted rock lying in lumps in the flatlands over an area but a few rods across, three miles west of West Palm Beach.

The marine limestones seen are classified on the basis of lithology and areal extent as the Palm Beach limestone, Miami oolite, Key Largo limestone, Key West oolite and Lostmans River limestone.

PALM BEACH LIMESTONE.

Synonymy:—Reference to the limestone on the east side of the Everglades and to limestone forming the eastern rim appear in various early accounts of travelers and of army officers who traversed the Everglades, but no distinctive term has been applied by any one, so far as is known, to the inconspicuous outcrops of limestone sparsely scattered through the pineland, cypress swamp and prairie along the eastern side of the Everglades from Delray northward. The term Palm Beach limestone is here used to distinguish these non-oolitic marine limestones because the outcrops are found throughout a considerable extent of country in the eastern part of Palm Beach County. Though the outcrops are few and separated, it seems probable that the limestone extends northward into St. Lucie County and is the equivalent of limestones described by Matson and Clapp, in the earlier pages of this report.

Stratigraphic Position:—As the exposures are all low, mere heads of rock, projecting a few inches to a foot above the surrounding sands, and as there are no good sections showing the rock, so far as reported, along any of the rivers that flow from the Everglades, little is known of the stratigraphic relations of the Palm Beach limestone. It is overlain by the sands of the pineland and the sands and peat of the Everglades. It is underlain, so far as can be told from the records of the few wells that have penetrated it, by marl and sand.

Seaward it may grade into coarser and less solid rock overlain by the deposits of coquina forming the backbone of some of the barrier beaches of the east coast. The limestone has not been seen in contact with the coquina and the exact relations remain to be proved. To the south the limestone may underlie or grade into the Miami oolite, but the two have not been seen in contact.

Lithologic Characteristics:—At the type locality in T. 45, R. 41, twelve miles west of Lantana, the rock is a white to yellowish limestone, containing a variable proportion of fine to medium quartz sand. The lime cement is not coarsely crystalline, nor does the rock contain, like other limestones of southern Florida, many patches and streaks of coarsely crystalline calcite, replacing amorphous material or filling cavities left by the solutions of shell fragments. Its hardness varies greatly; in some places it is compact, dense and rings under the hammer; in others, the proportion of sand is so great that the rock becomes a friable calcareous sandstone.

Thickness:—Owing to the low elevation of the belt of country where the outcrops are found and the horizontal position of the limestone, the only evidence available to determine the thickness is that of well records. The testimony of these is contradictory, as is to be expected from the fact that most of them are given from memory. Such evidence as can be had, however, indicates that the limestone may be from five to fifty feet thick.

Physiographic Expression:—From the low relief of the pinelands and the monotonous flatness of the ground, it can not be said of the Palm Beach limestone that it contributes to the physiography of the country. It helps, however, to define the eastern boundary of the Everglades for possibly thirty miles.

Paleontologic Characteristics:—The Palm Beach limestone is, as a whole, abundantly fossiliferous. The fossils comprise gastropod and pelecypod shells, all of marine type and probably of living species. Corals, as is to be expected from the sandy character of the limestone, are rare or absent. In places, the rock is full of shells of *Chione cancellata,* nicely bedded, with both valves closed, indicating that the shells had not been disturbed since the mollusks died. The limestone thus has the facies of a shallow water deposit formed in bays or lagoons with bottoms of sand or sandy marl.

Areal Distribution:—The northernmost exposure of the Miami oolite that the writer saw was in T. 47, R. 42, five miles south and seven miles west of Delray. The southernmost exposure seen of non-oolitic limestone is over five miles to the north. There are outcrops between but they are scattered and were not visited as it was thought doubtful if any direct transition from oolitic to non-oolitic beds could be found or any line of demarcation established. The northern limits of the formation are undefined. As before stated, it probably extends into St. Lucie County. But little is known of its western extent under the Everglades, while seaward it is buried by sand.

Structure:—The rock is not as distinctly cross bedded as are many exposures of the Miami oolite and the beds are rather heavier. The sandy layers at the type locality west of Lantana are two or three inches thick, while the limy beds may be a foot or more thick.

MIAMI OOLITE.

Synonymy:—The outcrops of oolite at New River, Miami River, Long Key in the Everglades, and at other points in southeastern Florida were noted by army officers at the time of the Seminole War. The first writer to recognize the age of the deposits appears to have been Buckingham Smith who in 1847 noted the many shells of mollusks in the oolite at Miami River and determined the age as post-Pliocene.[1]

In 1851 Tuomey described outcrops of the rock also on Miami River,[2] and in the same year L. Agassiz mentioned them in his account of the Florida reefs.[3]

Shaler in 1890, following the views of L. Agassiz, regarded the oolitic limestone at New River and Cocoanut Grove as formed on a coral reef and included it and other rock, possibly coquina, in his Miami Reef.

A. Agassiz in 1895 stated that he believed the limestones at Miami and Cocoanut Grove to be of aeolian origin,[4] and in a paper published the following year gave his reasons in detail.[5] His views were not accepted by Griswold who saw the rock not only along the water front but some twenty miles inland.[6]

All the exposures of oolitic limestone on the mainland of southeastern Florida are in this paper included under the designation of Miami oolite.

---

[1] Smith, Buckingham. Report on Reconnoissance of the Everglades made to the Secretary of the Treasury, June, 1848.

[2] Tuomey, M. Notice of the Geology of the Florida Keys and of the Southern Coast of Florida. Am. Jour. Sci. (2) xi, 1851, pp. 390-394.

[3] Agassiz, Louis. Florida Reefs, Keys and Coast, U. S. Coast Survey Report for 1851; (Appendix No. 10), 1852, pp. 145-160.

[4] Agassiz, Alexander. Note on the Florida Reef. Am. Jour. Sci. (3), xlix, 1855, pp. 154-155.

[5] Agassiz, Alexander. The Elevated Reef of Florida. Mus. Com. Zool. Bull. xxvii, No. 2, 1896, pp. 29-62.

[6] Griswold, Leon S., Notes on the Geology of Southern Florida. Mus. Comp. Zool. Bull. xxvii, No. 2, 1896, pp. 52-59.

Stratigraphic Position:—The relations of the Miami oolite to the other limestones described in this paper are not definitely established. The extent of the oolite north, west, and southwest is obscured by sand or swamp deposits. The rock is perhaps younger than the Palm Beach limestone and is younger than the lower part of the Key Largo limestone. It lies almost flat.

While the Miami oolite is so overlain by unconsolidated deposits that its field relations can not be determined with exactness, well records and samples from a few wells show what is below it at several places. At Miami samples from the wells of the water company show that the oolite loses its typical appearance a few feet below sea level and rests on an irregularly cemented aggregate of shell fragments and quartz sand. At Dania the oolite rests on "blue mud," at Fort Lauderdale on "sand."

Lithologic Characteristics:—Typically the rock is a soft white oolitic limestone, containing streaks or thin irregular layers of calcite separating less crystalline streaks. The rock breaks with an irregular fracture, dresses nicely, hardens on exposure and makes good road metal and building stone.

Hand specimens show that the oolite carries a varying proportion of quartz sand. The grains are mostly small and angular to subangular in outline; occasionally there is a large, rounded grain. On the average the grains are considerably smaller than the ovules, which have a mean longest diameter of ¼ to ½ mm.

The proportion of quartz sand is greatest to the north. Along the drainage canal west of Fort Lauderdale there are found in the oolite streaks of sand so loosely cemented that perfectly preserved shells of *Chione cancellata* can be picked out with the fingers, while at Long Siding quartz grains in the oolite are relatively rare. Besides being more plentiful to the north, the sand grains seem to form a larger proportion of the rock near Biscayne Bay than farther west, as on Long Key.

Examination with the microscope shows that the ovules have a well marked concentric structure; the nucleus of some ovules is a rounded aggregate of minute calcite crystals, of others a rounded aggregate less-evidently crystalline; sometimes the nucleus is a shell fragment and frequently it is a grain of quartz. The concentric layers vary in number from one to four or five, and in appearance from clear and rather coarsely crystalline to opaque, the layers are darker or lighter from varying amounts of organic matter and amorphous material.

Thickness:—A well at Fort Lauderdale, according to the driller, went through twelve feet of oolitic limestone, one at Dania forty feet of oolite, and the wells of the Miami Water Company found about

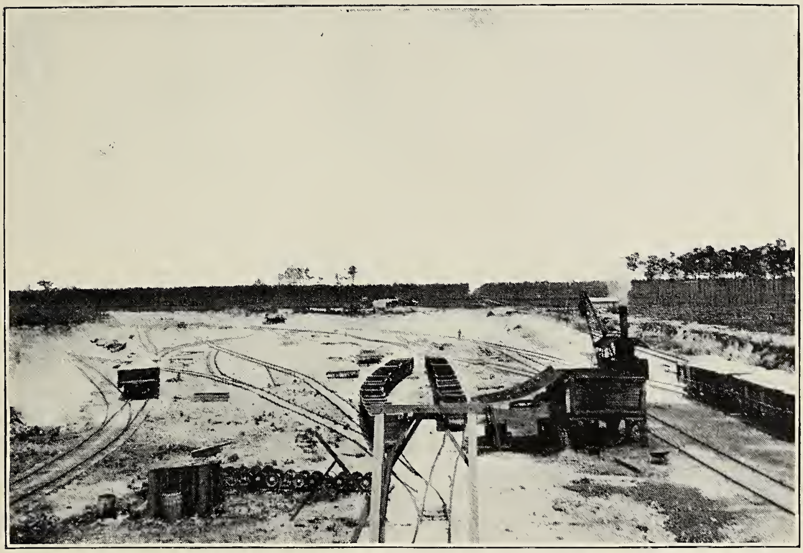


FIG. 1.—QUARRY IN MIAMI OOLITE, KEYS STATION, DADE COUNTY.

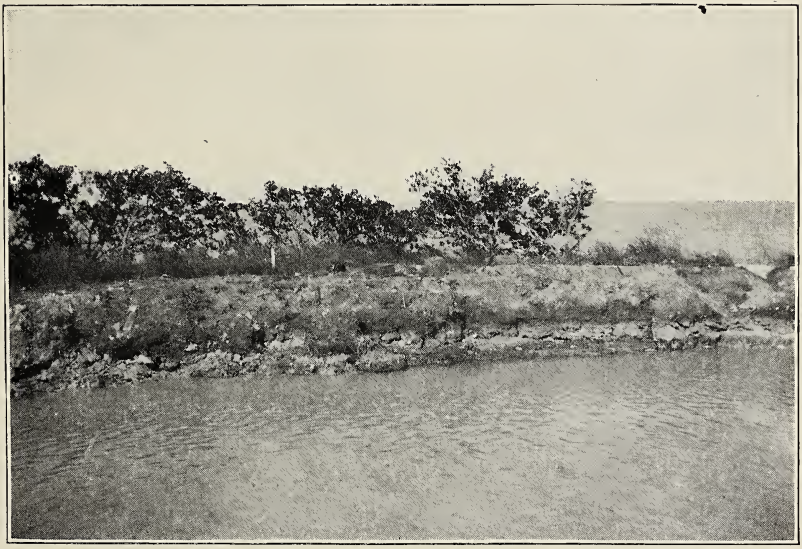


FIG. 2.—REEF ROCK OVERLAIN BY MARL, KNIGHTS KEY.

twenty feet. These figures, making due allowance for the scantiness of the data and the unreliability of well records unless accompanied by samples, shows that the maximum thickness may be fifty feet along the coastal outcrops and perhaps more inland.

Physiographic Expression:—L. Agassiz and subsequent observers noted that the oolite ledges near Miami and Cocoanut Grove have a steep seaward face, and slope off in a succession of low ridges toward the Everglades. Shaler also noted along the bluff back of the present shore, evidences of erosion by waves indicating an uplift of the coast. The ridges back from the bluff appear to have a general trend to the west of north. The absence of soil, and quality of the rock surface, indicate that these ridges are to be accounted for by original manner of deposition, or by erosion during uplift, and not by erosion since; yet, that there has been some removal of rock is proved by the potholes, large springs, and such water work as the Punch Bowl and the shallow gorge of Arch Creek.

The slight variations in elevation of much of the rock back of Biscayne Bay is indicated by the accompanying view of a large quarry for railroad ballast, at Key. (Pl. ix, fig 1.)

The maximum elevation of the ledges south of Miami may be thirty feet above sea level. The maximum elevation on Long Key in the Everglades is about eight feet, and at New River about eight feet.

Paleontologic Characteristics:—The Miami oolite varies in content of well-preserved fossils, but is a distinctly fossiliferous rock. The animal remains comprise molluscan shells, echinoids and corals. The corals are not reef builders and one at least is plentiful in the Bay of Florida today. Collections by T. Wayland Vaughan near Miami in the winter of 1907-1908, yielded two species of corals and fourteen of mollusks, all sixteen species being Recent. Of twenty-six species collected along the drainage ditch west of Fort Lauderdale, by George C. Matson in the same winter, Dr. Vaughan specifically determined twenty as Recent, and one as Pliocene. Many small heads of coral (*Siderastrea*) were thrown up by the dredge.

Areal Distribution:—The most northern exposure of oolite known to the writer is west of Delray. The rock outcrops on Long Key and the neighboring keys in the Everglades, fifteen miles west of the southwestern corner of the Biscayne Pineland and was found by Griswold twenty miles west of Miami. How far west it extends under the Everglades, farther north than Fort Lauderdale, is not established.

Structure:—At the type locality, Miami, the rock is plainly stratified and crossbedded, as is shown by the accompanying photograph of a face in a quarry. The bedding is that of water-borne sediments. No regional tilt can be distinguished from the outcrops though the probabilities are that the formation has a slight dip to the west.

Correlation:—The contemporaneous deposition of coquina and oolite suggested by Shaler and accepted by Griswold can not be proved from any outcrops seen by the writer, but the contemporaneous deposition of the two seems possible.

KEY LARGO LIMESTONE.

Synonymy:—The elevated reef that forms the backbone of the main chain of the Florida keys from Soldier Key to Bahia Honda has been recognized as made up of coralline material by practically all the writers who have described the keys in any detail. One of the first references is that of Henry Whiting, who called the rock a coralline limestone.[1]

The first reference to the keys representing an uplift is that of T. A. Conrad. He visited the keys in the winter of 1842, and besides correlating the evidences of elevation there with other evidences in northern Florida, determined the age of the reef rock as post-Pliocene.[2]

Tuomey visited the keys in 1850 and noticed the large heads of coral in the reef rock at Key Vaca, Indian Key, and elsewhere. He stated very clearly: "There can be no doubt that this great chain of keys is due to the elevation of a vast uneven coral reef whose prominent points rising above the water form the foundation of the keys, the sands driven up by the waves having done the rest."[3]

L. Agassiz and LeConte visited the keys in 1851. Agassiz gave an accurate description of the coral rock but positively denied the evidences of elevation seen by Conrad and Tuomey, believing that the coral boulders had been thrown up by hurricanes and cemented by calcareous sands and mud; the keys having been built up to their present elevation above sea level purely by the action of the waves and winds; making the rock "sub-aerial, not a marine accumulation."[4]

This view of the rock above sea level having resulted from the cementation of material thrown up by the waves was shared by Hunt[5] and LeConte.[6]

---

[1] Whiting, Henry. Cursory Remarks on East Florida in 1838; Am. Jour. Sci. (1) xxxv, 1838, pp. 47-64.

[2] Conrad, T. A., Observations on the Geology of a Part of the coast of East Florida, Am. Jour. Sci. (2) ii, 2846, pp. 36-48.

[3] Tuomey, M. Notice of the Geology of the Florida Keys and of the Southern Coast of Florida, Am. Jour. Sci. (2) xi, 1851, pp. 390-394.

[4] Agassiz, Louis. Florida Reefs, Keys, and Coast; U. S. Coast Survey Report for 1851 (Appendix No. 10), 1852, pp. 145-160.

[5] Hunt, E. B. On the Origin Growth, Substructure and Chronology of the Florida Reef; U. S. Coast Survey Report, App. No. 25, 1862, pp. 241-248.

[6] LeConte, Joseph. On the Agency of the Gulf-Stream in the Formation of the Peninsula of Florida; Am. Asso. Adv. Sci. Proc., 1857, pt. 2, pp. 103-119.

In 1883 A. Agassiz published a paper on the keys, in which he attributed their western growth to a return eddy of the Gulf Stream, previously postulated by Hunt, and said[1] (pages 108-109): "The line of keys seems to be formed by the waste of the exterior present reef rather than by the remains of an older reef." He recognized that the Tortugas were younger than the keys to the east, saying that the deposits composing them "have not as yet been transformed into the normal coral rock."

On a subsequent visit to the keys, Agassiz saw the evidences of elevation and confirmed the conclusions of Tuomey.[2] He elaborated his views of the growth of the keys in the most comprehensive account of their geology and topography that has yet appeared.[3]

The recent construction work of the Florida East Coast Railway has shown the character of the rock from where the railroad bends southwest on Key Largo to the west end of Knights Key. Borrow pits expose the limestone not only where it was lightly covered by leaf mould but where buried under several feet of marl and sand, and have determined its character where it lies, as in channels between the keys, ten feet or more below sea level. Hence, the opportunity for observing the various phases of the rock and for determining its origin is incomparably better than when A. Agassiz visited the keys in 1894.

On Key Largo, cuts and borrow pits expose the limestone at frequent intervals from the south shore of Lake Surprise to the west end of the island at Tavernier Creek, a distance of fifteen miles. As this is the longest series of exposures on any of the keys, the reef rock is here designated the Key Largo limestone.

Stratigraphic Position:—As the Key Largo limestone represents the only known fossil coral reef in southern Florida it forms a lithologic unit and is sharply differentiated from any of the other limestones of the mainland and keys. Having been built up from the bottom from a depth perhaps of over 100 feet during a considerable interval of time, it may in part be contemporaneous with the other limestones, and in part may be older, as these limestones are believed to represent shallow water deposits, some of which accumulated behind the reef while the latter was growing and finally extended over it. In places the Key West oolite apparently rests on the Key Largo limestone; the relations to the Miami oolite and the Lostmans River limestone are less certain.

---

[1] Agassiz, Alexander. The Tortugas and Florida Reefs; Am. Acad. Mem. II, 1883, pp. 107-134.

[2] Agassiz, Alexander. Note on the Florida Reef; Amer. Jour. Sci. (3) xlix, 1895, pp. 154-155.

[3] Agassiz, Alexander. The Elevated Reef of Florida; Mus. Com. Zool. Bull. XXVIII, No. 2, 1896, pp. 29-62.

Lithologic Characteristics:—The Key Largo limestone is extremely variable in appearance and structure. Like the reef rock of the southern Pacific, described by Dana;[1] it is "solid limestone of coral origin; * * * in some parts it is a coral conglomerate; * * * over much larger areas a fine white limestone; * * * it is often free from any proofs of an organic origin. It breaks with a conchoidal fracture, a splintery surface, and rings under the hammer. * * * Other portions are made of standing corals with the intervals filled in by reef debris, and the whole cemented solid."

Since solidification of the rock, there has been much solution and redeposition of calcareous matter. In places the rock contains heads of coral replaced by clear, rather coarsely crystalline calcite, showing quite plainly the structure of the original head. In places the rock is a typical breccia composed of angular and cherty fragments in a limy cement, this cement and many of the fragments being often bright red. These breccias evidently represent loose material that has fallen into solution cavities, and been recemented, the red color being due to iron oxide. The rock is harder within a few feet of its surface than below. This is true, not only of the ledges which are bare, but of those below sea level. Besides this general surficial hardening, the rock shows in many places on unweathered surfaces a thin layer, usually less than two inches thick, and never, so far as seen, one foot thick, that is darker than the rock below and is finely banded. In this layer all traces of the corals and shells visible in the mass of the rock disappear. The crust follows slight inequalities of surface and is perhaps due to a deposition of limy ooze in pools or hollows which began after the elevation of the reef and may be still in progress.

Some other features of the rock were brought out by the railway work along the keys. Measured in terms of a day's work with a hand drill, the rock is twice as hard as the Key West oolite. Yet, while hard, it is so honeycombed with solution passages that many borrow pits instead of yielding more loose rock than the cubic contents of the pit actually yielded less.

Thickness:—The only information available regarding possible variations in thickness of the Key Largo limestone is that of well records. Its presence below Jackson Square in the city of Key West was not shown by the samples of borings described by E. O. Hovey,[2] but at Key Vaca a well has shown reef rock fully 100 feet thick; at Indian Key over 130 feet of reef rock was indicated by a record given by Hunt, but at Indian Key Channel the thickness may be about sixty-nine feet.

---

[1] Dana, J. D., On Coral Reefs and Islands, Am. Journ. Sci. (2) XIV, 1852, p. 76.

[2] Hovey, E. O., Notes on the Artesian Well Sunk at Key West, Florida, in 1895. Mus. Comp. Zool. Bull. XXXVIII, 1896, pp. 65-91.

Physiographic Expression:—The causes determining the outline of the great arc of the reef have already been discussed. The islands form a discontinuous low wall separating the waters of the Atlantic from those of Biscayne Bay, the Bay of Florida, and Blackwater and Card Sounds. Mention has already been made of the average and maximum elevation of the rock surface, the depths of the surrounding water, the outlines of the keys, and the weathering of the rock.

The work of water is shown by the numerous vertical holes forming natural wells, or, as they are called, springs, and the many shallow hollows or potholes. These potholes seldom reach much below sea level. Occasionally a hole may run down twenty feet, and cases have been noted of free openings or cavities filled with soft material that extended thirty feet below sea level. Yet, though the rock is full of holes, it is not cavernous. Most potholes end in crevices or passages filled with loose material, without free openings of any considerable size. Holes a foot in diameter extending more than a very short distance from a surface opening are rare.

The reef rock along beaches presents above mean high tide mark a curiously rough and jagged look, due to the solvent effect of spray. Between tide levels the faces of the low ledges are undercut by the waves. Often a loose slab looks as though it had been thrown up by the sea, or an apparent heavy bedding slopes toward the water, giving the appearance of beach rock. Examination shows that the loose slab and the apparent bedding are erosion effects, due to solution and cementation. The look of a spray-worn beach is shown in the accompanying illustrations. (Pl. x, fig. 1.)

Paleontologic Characteristics:—The Key Largo limestone shows a rather small variety of fossils recognizable to the naked eye, though heads of corals standing as they grew are frequent, and occasionally, an overturned head such as may be seen on the present reef is visible. All the corals are of living species. Determinable shells are not especially common, though aggregates of shell fragments are found from place to place. Among the most common molluscan relics are the holes made by various lithodomes in the coral. In addition to mollusks, foraminifers, coralline algae and echinoids have contributed to the formation of the rock. The fossils indicate the post-Pliocene age of the reef.

Areal Distribution:—The total length of this Pleistocene coral reef is still undetermined. Its continuity from Soldier Key to Bahia

---

[1] Hunt, E. B. Op. cit. p. 205.

Honda, ninety miles, is undisputed. Virginia Key north of Soldier Key is covered with sand, but is probably underlain by the reef rock. The farthest northward growth of Pleistocene reef building corals known is to Hillsboro Inlet, ten miles north of New River. On the east side of the Florida Coast Line Canal, just south of the Inlet, can be seen fragments of large heads of reef-building corals (*Orbicella, Maeandra*) that were blasted out in dredging the canal. According to Captain Gleason, who had charge of the dredge, no coral rock was found in the work south of this ledge. It is possible that these heads formed an isolated patch a mile long and that the main reef never extended so far north.

Reef rock is occasionally exposed at about low water mark on the south shore of Bahia Honda. To the west it shows on the south face of Big Pine Key and on one of the New Found Harbor Keys, though obscured in places by angular compactly-cemented fragments of recent beach rock. It does not show on any of the larger keys farther west, though boulders of coral rock were found, according to L. Agassiz, twelve feet below surface at Fort Taylor, Key West. The rock outcrops on Sand Key south of Key West and probably extends under water a considerable distance westward. Thus, the possible length of the Pleistocene coral reef of southern Florida was close to 200 miles. There is no evidence to prove its maximum width. The maximum width shown by exposures above sea level may be three miles.

Exposures:—The best exposures of the Key Largo limestone are in the quarry at Windleys Island where are vertical faces fourteen feet high. Other good exposures appear in the railroad cuts on Plantation Key, just east of Snake Creek, and on Key Largo south of Lake Surprise. The cuts and the many borrow pits show the varying structure of the rock and its coral origin. The bedding that characterizes most detrital rocks is nowhere visible. The peculiar features of the shore line erosion of the rock can be seen at many promontories and detached islets along the north side of Key Vaca.

KEY WEST OOLITE.

Synonymy:—The first distinctive reference to this rock appears to be that of G. W. Featherstonhaugh, who, at a meeting of the New York Lyceum of Natural History in September, 1828, exhibited samples of oolite from Key West.[1]

Conrad on his visit to the keys in 1847,[2] suggested the post-Pliocene age of the rock. Tuomey, in 1850,[3] noted the oolite and com-

---

[1] Amer. Jour. Sci. (1) XVI, 1829, p. 206.

[2] Conrad, T. A., op. cit., pp. 36-48.

[3] Tuomey, M., op. cit., p. 390.

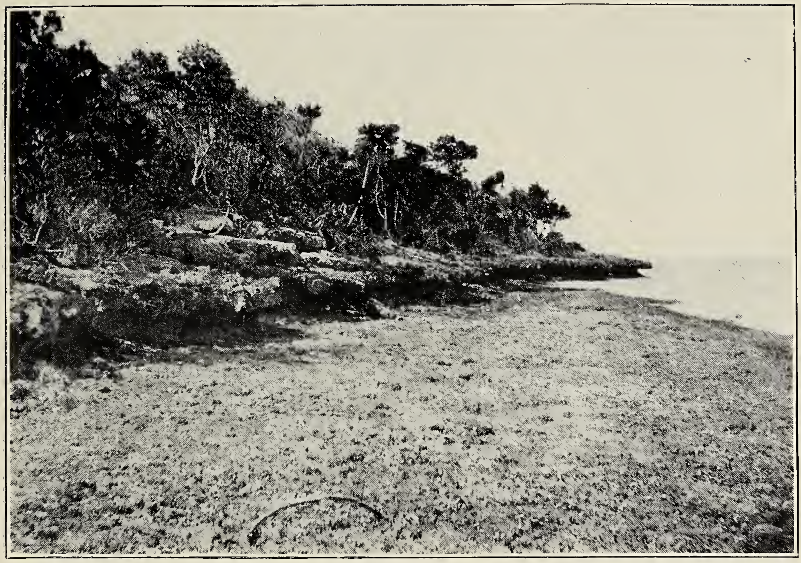


FIG. 1.—EROSION BY SPRAY IN KEY LARGO LIMESTONE, KEY VACA.

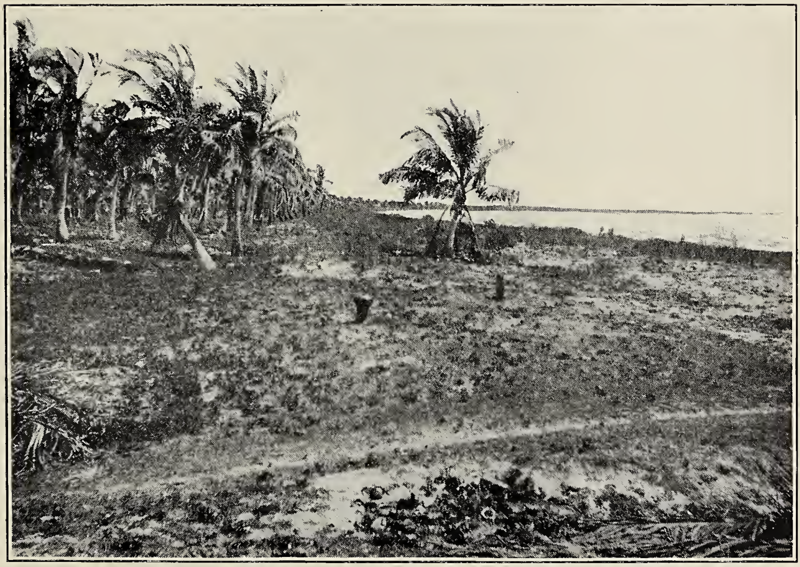


FIG. 2.—BEACH RIDGES OF CALCAREOUS SAND, CAPE SABLE.

pared it to recent deposits along the keys and in 1852, L. Agassiz,[1] described the rock in some detail. Hunt believed that the oolite had formed from the consolidation of limy material similar to that accumulating about the keys; while A. Agassiz thought that the Key West, like the Miami oolite, had an aeolian origin. All the oolite outcropping on the keys south of Florida Bay is here designated the Key West oolite.

Stratigraphic Position:—On the south side of Big Pine Key and on one of the New Found Harbor Keys the Key West oolite apparently overlies the Key Largo limestone. Its relation to the non-oolitic rock called in this paper the Lostmans River limestone cannot at present be determined, since the contact or, possibly, line of gradation between the two lies under the Bay of Florida. The oolite is overlain by recent marls and calcareous sands and in places along the shores of the keys may have a thin veneer of beach rock.

Lithologic Characteristics:—Typically the Key West oolite is a soft white or light-colored fossiliferous oolitic limestone, the ovules being scattered through amorphous carbonate of lime or surrounded by a crystalline cement that develops most freely along bedding planes. The ovules on the average have a longest diameter of about ½ mm. The rock is less sandy than the Miami oolite, but resembles the latter in general appearance and physical qualities, there being little difference between hand specimens of the two.

Like the Key Largo limestone, the Key West oolite shows on many unweathered exposures a thin, dark crust, finely banded, of more or less amorphous carbonate of lime. In this crust all traces of oolitic structure disappear. The rock frequently shows cross bedding, but not so conspicuously as does the Miami oolite. It is easily quarried and dressed; makes a fair building stone and good road metal.

Under the microscope the oolitic ovules of the Key West rock resemble those of the Miami rock. The nuclei of the ovules are mostly rounded calcareous grains; occasionally a grain of quartz is a nucleus. The general appearance of the ovules indicates a formation in unconsolidated material in the presence of water.

Thickness: — The maximum thickness of the oolite is unknown. Several wells over fifty feet deep have been sunk at Key West, but from only two of these were samples preserved. A well sunk near the plant of the Consumers Ice Company, according to the driller, penetrated sixty-five feet of rock of the same general character as that at the surface. Samples from the deep well in Jackson Square have been described in much detail by E. O. Hovey.[1] From them Hovey concluded that the Pleistocene rock at Key West was but twenty-five to fifty feet thick. There can be no question as to the accuracy of Dr. Hovey's description, but it seems doubtful whether the samples were taken and labeled with equal accuracy. Hence the evidence of the samples is not conclusive. East of Key West no section of greater depth can be had than those of the excavations along the line of the Florida East Coast Railway, and from none of these was material taken at a greater depth than ten feet below sea level except in some of the crossings between the keys where the maximum depth may have been more. So far as the writer knows, all of the material shot up between Big Pine Key and Key West was oolitic. A well at Big Pine Key went through the oolite; the exact thickness there is uncertain, but is probably less than fifty feet

---

[1] Agassiz, L., op. cit., pp. 145-160.

Physiographic Expression: — As the Key West oolite covers the islands west of Bahia Honda Channel to Key West, the distribution of the outcrops is quite different from that of the Key Largo limestone, the islands west of Bahia Honda lying in an irregularly triangular archipelago instead of a long thin line. The relief of these islands is nowhere fifteen feet, the highest land on the largest of the islands, Big Pine, is but thirteen feet above tide, as is the highest ground on Key West. On many of the keys between Big Pine Key and Key West bed rock barely reaches to sea level, the islands being low-lying flats of marl with many patches of mangrove swamp that are inundated to a depth of five feet during hurricanes.

Like the Miami oolite the Key West oolite weathers easily, but its surface nowhere has the rough and jagged appearance of the rock in the Biscayne pineland. While roots have disrupted angular blocks the surface in general is smooth and over many areas as extensive as 100 square yards shows no sign of roughening by decay.

Small vertical holes of varying size and shallow hollows characterize the outcrops. The holes communicate frequently with underground water channels which often are larger than those found in the Key Largo limestone. In places these passages contain salt water a quarter of a mile or more from the shore line, and must be comparatively free openings of considerable extent.

Paleontologic Characteristics: — The abundant marine fossils in the Key West oolite comprise remains of corals, echinoderms and mollusks, with foraminifera and other less evident fossils. Collections made by T. Wayland Vaughan on Torch Key and by the writer on Big Pine Key, give, according to Dr. Vaughan, a total of twenty-six species, of which two are corals, one an echinoid, and twenty-three mollusks. The corals were not of reef-building species and Dr. Vaughan found several delicate pelecypod shells with both valves closed, indicating that the shells had not been rolled about much. A study of the exposures on Big Pine Key shows that the shells as a rule are but slightly worn. All the fossils are living species.

---

[1] Hovey, E. O. Notes on the Artesian well sunk at Key West, Florida, in 1895. Mus. Comp. Zool., Bull. XXXVIII, 65-91, 1896.

Areal Distribution:—The rock outcrops on the shores of Harbor Key and Content Key and on most of the Keys south and southwest. It underlies the Bay of Florida for at least three miles southeast of Big Bahia Honda Key and forms the surface of Boca Grande, ten miles west of Key West.

ORIGIN OF FLORIDA OOLITES.

The Miami and Key West oolites differ so slightly, the chief differences being the greater percentage of quartz grains and stronger cross bedding near Miami, that they may be assumed to have had a common origin. Whether their origin was aeolian or whether it was marine is a point of interest. The evidence comprises the field relations of the rocks, their appearance in outcrops and their lithologic and paleontologic characteristics.

The oolites are presumably thin. At Dania they overlie "blue mud," at Miami quartz sands and worn shell fragments cemented by clear crystalline calcite separated by layers of sand containing nodules of quartz grains; at Key West the oolite aparently overlies a shallow-water lime-sand rock. Nowhere has the Miami oolite been proved to rest on an old coral reef.

Outcrops of oolite are not known north of Delray, on the east coast, nor anywhere on the west coast. While exposures form conspicuous bluffs near Miami and low ridges for a few miles west, yet much of the Miami oolite is flat topped, outcrops showing differences of less than five feet in elevation for miles toward Long Key. Long Key itself is nowhere ten feet above sea level. Nowhere on the mainland are ridges comparable with the siliceous sand ridge at Hobe Sound. The flat smooth tops of the oolite exposures in the keys west of Bahia Honda are one of their most striking features.

The cross-bedding of the oolite is more marked in some outcrops than in others; in some the cross-bedding is not at all conspicuous, the best cross-bedding is near the ocean or Strait of Florida rather than inland. The writer believes the cross-bedding is that of water-laid material; he can not see that it is like that of the wind-borne sands in the dunes at Cape Henry, Virginia.

The oolite is abundantly fossiliferous, in places containing delicate shells with valves adherent, in places shells of some size and heavy heads of non-reef-building corals. Buckhorn corals, so common in present beach ridges of coral sand, are rare in the oolite exposures seen by the writer.

An oolite from China examined by Blackwelder,[1] exhibited peculiarities which indicate that the concentric structure of the ovules developed when the material composing the rock was loose and somewhat mobile—a calcareous mud. The microscopic structure of the Key West and Miami oolites suggests an underwater origin for the ovules. The rounded aggregates of calcite that serve as nuclei are like aggregates now lying on the bottom of the Bay of Florida. Hunt thought he saw one case of incipient oolitization in marl at Key West.

The characteristics of the calcareous sands and marls accumulating about the keys and in the Bay of Florida, and the distribution, topographic relief, bedding, contained fossils and structure of the Key West and Miami oolites indicate that the latter were originally limy muds, with a varying proportion of lime sand and a little quartz sand, which accumulated on the bottom of shallow bays or lagoons, where in places the water was relatively still, in places agitated by waves and currents strong enough to build up and level off banks and bars. Conditions approaching these exist in many exposures of water about the keys. That oolites may be forming now on the Bay of Florida is possible. That they will be found in process of formation is not certain. Examination of material from the surface of banks will probably give negative results, examination of material buried for some time may give positive results.

LOSTMANS RIVER LIMESTONE.

Synonymy:—This term is applied to the non-oolitic fossiliferous limestones which apparently underlie the western coast of southern Florida and outcrop inland. Though doubtless noted by army officers at the time of the Seminole War, and by other observers since, the first published description of these limestones which the writer has been able to find is that of Dall,[2] who described samples collected by Willcox in the winter of 1887-1888 at the head of Allens River and in Lostmans River.

Willis[3] subsequently examined the samples and took certain peculiarities of those from Lostmans River and points in Dall's description of the location from whence they came as showing that the rocks might be in process of formation.

---

[1] Blackwelder, E. Researches in China, 1907, p. 380.

[2] Dall, Wm. H., and Harris, G. D. Correlation Paper; Neocene of North America; U. S. Geol. Sur. Bull. 84, 1892, p. 100.

[3] Willis, Bailey, Journal of Geology, I, 1892.

The writer groups all the west coast non-oolitic limestones showing marine fossils as a single formation, although they vary considerably in appearance.

Stratigraphic Position:—These limestones underlie the gray sands of the mainland, the marls of the coastal swamps and the keys of the southern portion of the Ten Thousand Islands. They also extend along the southwestern border of the Everglades. Their relations to the non-oolitic marine limestones designated as Palm Beach limestone cannot be determined, the great saw-grass swamp of the Everglades separating the nearest exposures. The minimum interval between outcrops is about thirty-five miles. The relation to the Miami oolite cannot be determined with exactness, though from samples collected along the Florida East Coast Railway between Long Siding and Jewfish Creek, the writer believes that the oolite is younger than the non-oolitic limestones which lie south of it. Outside the shore-line of the mainland, the rock lies below sea level, and its relation to the Key West oolite across the Bay of Florida has not been established.

A well drilled through the rock at Everglade showed that the limestone rested there on a fine gray sand. It is uncertain whether or not the limestone was struck at Marco. Possibly it was not and the limestone may be represented there by unconsolidated quartz sand and shell fragments.

Lithologic Characteristics:—The Lostmans River limestone varies so greatly that it is impossible to give a description that contains features common to all localities. At the type locality on Lostmans River, the rock is described by Dall as very hard and consisting of large masses of Polyzoa more or less completely changed into crystalline limestone. The cavities are filled with crystals of calc-spar. Hand specimens show individual crystals an inch long. All the samples collected by the writer from Lostmans River and from below water level in Allens and Turners Rivers had common features. Near Deep Lake the rock is softer and more friable. Rock from the head of Hendersons Creek contained much more sand than specimens collected to the south, and in samples collected at several localities in White Water Bay from its mouth to its eastern extremity, a distance of nearly twenty miles, the proportion of quartz sand in hand specimens is very small, and microscopic sections show sand but rarely. Between Jewfish Creek and Manatee the rock is much less crystalline than on the west coast or toward the entrance to White Water Bay.

Thickness:—The formation is probably thin. The well at Everglade went through but thirty feet of it. A boring at the plant of the Minette Lumber Company near the mouth of Shark River penetrated over forty feet of hard rock.

At Marco the limestone may run out and be represented by unconsolidated material. No wells have been drilled inland through rocks that can as yet be correlated with the Lostmans River limestone. The nearest deep wells to the east of Cape Romano are those on cattle ranges in Tps. 47 and 48, Rs. 31 and 33. According to the driller, H. Seniff, of Fort Myers, no hard rock was found in these wells near the surface.

Areal Distribution:—Marine limestones have been found to underlie the shore of the mainland wherever samples have been collected, from Jewfish Creek westward and northwestward to near Marco. They outcrop in the southernmost patch of the west coast pineland three miles northeast of the head of Rock Creek and at the heads of Turners and Allens Rivers and Hendersons Creek.

At Everglade the writer was told that limestones are found in the hammock land about Deep Lake, twelve miles to the east, and at Hendersons Creek he was informed that outcrops making bare ridges occur in the pineland. Limestone is also reported along the road from Fort Myers to Fort Shackelford, but the marine origin of exposure more than 20 miles from the coast of southern Florida has not been established.

Origin:—Willis[1] has suggested that the rock at Lostmans River was perhaps formed by the deposition of crystallizing calcium carbonate from the presumably limy waters of the Everglades. While there can be no doubt that deposits of marl are now accumulating along the coast, the present hardening of marl to crystalline limestone or the direct deposition of such limestone is not established. As the writer has stated, the bed rock of the western coast, wherever soundings have been made, whether in the Everglades, on swamp islands, along the coast, or in the numerous creek channels, seems to have a gentle slope toward the Gulf. The rock is no farther below water level in the swamp than in adjacent channels; moreover, the rock surface in channels where the current runs strongly, is full of crevices, is extremely rough, and is evidently being eroded. Loose fragments that have been detached by solution are found, not only near the mouths of rivers, but at their heads, on the bare rock, under marl, and under vegetable muck. Another fact that impairs the deposition and crystallization theory is the character of the Everglades water. Most of the marl in the Ten Thousand Islands has come from the ever-dirty shallows of the Gulf. The dark limestones below water in the creeks are the same as those that outcrop above water a short distance away, and a recent crystallization from solution of those is hard to understand.

---

[1] Willis, Bailey. Journal of Geology, I, 1893, pp. 512-514.

The limestone on Lostmans River, though containing calcite crystals an inch long, is not greatly different from other limestones of southern Florida; removal, deposition and crystallization of carbonate of lime are characteristic of the region.

The limestone, from its petrographic and paleontologic characteristics, is a shoal water deposit of marl and limy sand, containing shells of living species of mollusks, that has been solidly cemented and subjected to conditions favoring crystalline growth. This growth may be in progress.

COQUINA.

The word coquina is here used, as it is used on the east coast, to designate those deposits of cemented shell fragments and quartz sand that can be seen at many localities near the present ocean shore of southern Florida. In some exposures noted by the writer the rock bore slight resemblance to the long-known occurrences on Anastasia Island, being a rather fine-grained dense gray sandstone that rang under the hammer. This is probably the rock Griswold saw interstratified with coquina (shell rock) near Linton.

All phases between shell rock and material which is made up mostly of quartz sand can be found near Hillsboro Inlet, Delray and Palm Beach. At the spouting rocks some miles south of Hobe Sound the rock contains quartz grains, coarse and fine, and much worn fragments of shells (including axial pillars of conchs over a foot long) the whole so solidly cemented that the seaward face of the ledge worn into shallow grottoes, resists the breakers well enough to make a feature of unusual interest, the only spouting horn on the Atlantic coast of the United States south of Newport, R. I.

Coquina outcrops at Jupiter Inlet, along the east and west shores of Lake Worth, at Boca Ratone and at Hillsboro Inlet. It was found in the Florida Coast Line Canal at the cut to Indian River, the cut below Hillsboro Inlet and near Boca Ratone. The ledges seldom make rock knolls, though east of Hobe Sound are several knolls, the highest according to Mr. Grant of the Indian River Association, who has surveyed much of the island, having a maximum elevation of thirty feet above sea level. Its greatest extent inland is undetermined; as exposures seem to be confined to localities within a few miles of the beaches, it may be represented inland by unconsolidated material. In the canal south of Hillsboro Inlet the coquina apparently extended over fossil coral heads. No ledges of rock resembling the east coast coquina have been reported from the west coast of southern Florida.

The predominance of well-worn material in the coquina indicates an origin from sands that accumulated on barrier beaches or on bars when the surf had full swing. Certain features of the outcrops east of Hobe Sound suggest that the coquina there has acquired at least part of its hardness above sea level. One of the facts testifying to such consolidation is the presence at the spouting rocks of numerous vertical tubelike streaks of crystalline calcite which end in minute stalactites, indicating a downward movement of lime-charged water through passages between sand grains.

Coquina has been quarried for road metal at several localities along the east coast. For this purpose it is not so satisfactory as the Miami oolite, the coquina is not so calcareous as the oolite, is loosely cemented, where quarried, and breaks up instead of packing solidly.

SANDS.

The widespread mantle of sand that is so striking a feature of the central part of the peninsula extends into southern Florida as far as Miami on the east coast and to south of Everglade on the west coast. The sand is composed of angular grains of quartz, varying considerably in size. At the surface the sands are white or gray, below the surface they are of yellow, orange and red hues. The color is caused by iron oxide and represents the result of sub-aerial decay, the oxide coming from small grains of iron-bearing minerals, scattered through the sand. There seems to be no sharp dividing line between the gray and the colored sands, the intensity of color increasing with depth. The decoloration of the surface sands is due to the action of plant roots, the decay of vegetable matter and to leaching by rain.

In places there is yellow sand finer and apparently more decayed than the bulk of the gray sand and the sand of the dunes seems to be finer and more highly colored than that of the sand plains and flat lands, but there are so many gradations of size and hue that to separate the sands into gray and yellow seems a useless undertaking.

Whence came the sand is an interesting problem. Undoubtedly much of it represents the southward invasion of the peninsula by material worked down the Atlantic and Gulf coasts by waves and currents, the remnant of the material worn by streams from land far to the north. Some of it no doubt is all that is left of sandy limestones or marls that had accumulated below water level, and after partial or complete consolidation were elevated and worked over or leached, the limy material going away in suspension or solution. Possibly some of the sand now lying on the ground in southern Florida has been cemented to rock and reduced to separate particles many times since the grains were worn from some quartz-bearing rock in the hills of Alabama, Georgia or the Carolinas.

In journeying down the shores the sands have been moved by the wind, blown inland, and the contours of the dunes represent wind action, as do to a large extent those of the rolling sand plains.

LITHOLOGY OF PLEISTOCENE BEDS.

The summation of the evidence indicates, except along the keys, a larger proportion of siliceous material in the early Pleistocene beds than in the surficial limestones, and less consolidation of sediments. Considering the total bulk of the Pleistocene deposits, and the relative proportion of limy and sandy materials, the facts indicate that on the mainland the Pleistocene beds as a whole are not to be grouped as limestones. There are limy beds and limestones which can be mapped as lithologic units, but the proportion of siliceous and unconsolidated material is much greater than has been supposed.

THICKNESS.

The maximum thickness of the Pleistocene formations of southern Florida can not be determined from the available evidence. There was no distinguishable break in deposition nor sharp change in marine life to mark the beginning of Pleistocene time. The sequence of events shown by the sands, marls and limestones and the organic remains they contain is practically continuous. Pliocene time passed and Pleistocene time began with no distinct record of the change.

For this reason the total thickness of the Pleistocene formations can not be determined from the available evidence. It could be approximated with considerable exactness from a study of the fossils and a determination of the relative percentages of living and Pliocene species found in a given bed, but the drillers of the more important wells on the east coast saved few fossils. The evidence such as it is, shows that the Pleistocene beds are over seventy-five feet thick at West Palm Beach, over 118 feet thick at Delray, over fifty feet at Dania, fully 145 feet at Key Vaca and over fifty feet at Buck Key. Of the above measurements the only one that is at all definite is the Key Vaca. Fragments of reef building coral were found there at 100 feet. Below was marl and soft limestone with shell casts that graded downward into a sandy limestone (quartz sands) at 152 feet, this limestone continued to 176 feet and then the drill struck a clean white quartz sand, the first upper fifty feet of which contained many irregular nodules of quartz sand held by a limy cement. The changes from quartz sand to limestone at 176 feet, and from limestone to undoubted reef rock at about 100 feet, are suggestive but insufficient for drawing a sharp line between Pleistocene and Pliocene material. It is probably safe to say that below 176 feet are Pliocene sands, and above 105 feet is Pleistocene reef rock. Though the thickness of the reef rock at Key Vaca does not necessarily indicate the thickness of the Pleistocene beds at Palm Beach or the mouth of the Caloosahatchee River, yet taking all the data into consideration, the maximum thickness of the Pleistocene of southern Florida is probably about 125 feet.

RECENT.

The establishing of sharply marked limits for geologic time intervals is a difficult task, particularly in regions where there are no well-marked breaks in the stratigraphic succession nor sudden changes in the character of the fossil evidence. While there may be differences of opinion as to where the line between Recent and Pleistocene time, as applied to the geology of southern Florida, should be drawn, the writer includes as Recent all deposits that are being laid down or have been laid down since the last well-marked change in elevation of the land surface.

Most of the Recent deposits are unconsolidated; they include peat, marl and sand. The consolidated rocks embrace coquina, a few deposits of beach rock of no special importance, some of the mass of calcareous material made up of bits of corals, coralline algae, shells and other organic remains now hardening on the Tortugas; the growing coral reef outside the keys; worm rock and oyster banks.

PEAT.

Surficial deposits of peat are found throughout the Everglades where saw-grass grows tall and in places outside the main body of the saw-grass. They have resulted from the subaqueous, incomplete, decay of roots and blades of saw-grass and other swamp vegetation. The thickness of the peat varies greatly. In places the peat rests on rock; in places, especially toward the southern edge of the Everglades on marl; over considerable areas, as at New River, it rests on sand.

The average rapidity with which peat is now accumulating in the 'Glades is unknown, as is the rate of increase under the most favorable or most unfavorable circumstances. Hence the thickness of a peat bed at a particular place can not be used as a measure of the time that has elapsed since peat formation began there.

MARLS.

These include beach, swamp, lagoon and sea bottom deposits of finely divided calcareous material, differing in appearance, origin and manner of deposition. Some represent the rock, shell, or coral flour, ground up by the mill of the surf; some, as those accumulating in places in the Everglades and in pools along the coast of the mainland or the keys, represent lime that had been dissolved and later precipitated through the evaporation of the water that held it in solution, while other deposits, such as the marls accumulating on the bottom of Whitewater Bay, have been precipitated from solution in ways not clearly understood. From the first and third of these classes of marls have been formed the limy oozes that cover wide expanses of the bottom of the Bay of Florida, the inlets of the mainland, and the passages about the keys; tidal and wind-made currents have heaped them up into flats and banks, and through the growth of vegetation they have become islands. Such is the history of the gray marls on which flourish the mangrove forests of the Shark River archipelago and the Ten Thousand Islands.

SANDS.

The sands classified as recent are those of the shores, those that winds and waves move or bury in the work of destruction or construction. At Jupiter Inlet and Palm Beach, Hillsboro Inlet and even as far south as Cape Florida the beach material is quartz sand with a varying proportion of ground-up seashells and other calcareous material. From Soldier Key around nearly to Cape Romano the beaches as a rule are of calcareous sand. Quartz grains, however, occasionally appear as far south as the keys, and of a series of forty-seven samples from the bottom of the inside passages collected between Biscayne Bay and Bahia Honda by Dr. Vaughan and examined by Mr. Matson, nearly all show quartz grains, though the grains are fine and not particularly abundant west of Card Sound.

Along the shores of the keys from Soldier Key to Key West the beach sand consists of worn bits of corals, coraline algae and molluscan shells, with valves of pelecypods and whole shells of gastropods, and in many places, as at the sand pits on lower Metacumbe and Long Key, numerous branches of buckhorn coral (*Porites*). The thicker deposits of this sand, five to eight feet at Lower Metacumbe, show the material to be roughly stratified with inconspicuous cross-bedding; the material includes occasional fragments of rock a foot long and has neither the texture nor the arrangement of a purely aeolian deposit. The beach ridges near the west end of Long Key, 5 feet above mean tide, show that they have reached their present height during hurricanes. The work of relatively high waves is particularly evident in the outlines of the beach ridges on one of the inner keys—Sand Key, off East Cape, exposed to seas entering the Bay of Florida from the Gulf.

A striking peculiarity of these calcareous sands is their slight movement by the wind after the waves have heaped them up. Nowhere along the keys has the writer seen the sands moving before the wind, like the siliceous sands on the ocean shore at Palm Beach. As Hunt[1] observed, the calcareous sands, once packed "resist the blasts of hurricanes and northers."

CORAL REEFS.

Along the arc of the keys from Soldier Key to the Tortugas, from four to seven miles off shore, are growing corals that form the Florida reef. This reef is of the barrier type, separated from the keys by a shallow channel caused by the erosion of the elevated reef that shows above sea level from Soldier Key to Big Pine Key. The Florida reef is terminated at the west by the deep water west of the Tortugas. North of Biscayne Bay it dies away in scattered clumps and heads as the waters become too cool for vigorous growth. Fragments of reef-building corals come ashore on the beach opposite Hobe Sound station, and similar coral boulders are said to be washed up by the sea as far north as Canaveral Bight.

---

[1] Hunt, E. B. Origin, Growth, Substructure, and Chronology of the Florida Reef, Amer. Jour. Sci. (2) XXV, 1863, p. 197.

While of the barrier type the Florida reef does not rise from the sea floor as an almost continuous wall broken by a few narrow openings; it comprises heads and patches of coral rising irregularly, with many intervals where the bottom is covered by coral sand. These heads and patches grow in areas separated by breaks, some several miles long, where corals are few. The seaward face of these areas lies along an arc that in a rough way is concentric to the outer edge of the old reef. Along it the corals have grown up from depths of eight to ten fathoms. Seaward the bottom falls away and the 100 fathom line is within four to ten miles of the line of the outer coral patches. Toward the land in water five to twenty-five feet deep, heads and clumps of coral rise to the level of low tide several miles inside the arc of the patches.

At a few places along the reef, as at Sombrero Key, outer patches reach to tide level on which the waves have washed up coral sand and boulders enough to form small keys, a few rods across, with shifting shore lines. Thus the corals build a foundation for dry land, and the incipient land growth along the Florida reef led those who first wrote of the geology of southern Florida to believe that the keys themselves were formed in the same way, without uplift of the coast, and that coral reefs had been the principal agency in extending the Florida peninsula southward.

WORM ROCK.

Aggregations of the limy tubes secreted by a mollusk were seen and described by Dall[1] on the west coast. They are particularly noticeable around the shores of the outer keys between Cape Romano and Cape Sable. On the marly sand flats about Rabbit Key between tide levels, they form disconnected masses two feet thick, and fifty feet wide.

OYSTER BANKS.

Banks of solidly-packed oyster shells make reefs at the mouths of many rivers, particularly on the west coast. Good examples are found at Lostmans River and Caloosahatchee River.

---

[1] Dall W. H., and Harris, G. D. Correlation Papers; Neocene, U. S. Geol. Surv. Bull. 84, p. 153.

PLEISTOCENE AND RECENT HISTORY.

While the limestone formations that have been described apparently extend under wide areas, they are, except the Key Largo limestone, relatively thin. They grow sandy toward the north and rest on less consolidated material or on formations containing sandy beds and are more or less covered by sand and marl.

At some places along the east coast well records show a considerable thickness of coquina, and beds of well worn quartz sand and shell fragments; at others are relatively thin beds of limestone with sands and gravels above and below. Along the east coast and on the keys are rock outcrops fifteen feet or more above tide, along the west coast are none. The surface sands in some places are long, low ridges, in other mounds sixty feet high. These sand ridges often rise from ground where growth by wind action is now impossible.

The events of Pleistocene time thus outlined include a period of submarine upbuilding of quartz sands and limy material moved southward by currents; a gentle depression of possibly 100 feet during which beach or bar deposits thickened on the east coast and the coral reef grew and spread south of the mainland, while behind the bars and the reef and on the west coast quartz sands and limy sands and muds accumulated in wide expanses of shallow water.

Following this depression was a brief uplift of the land to possibly two hundred feet above its present level. Beach sands driven inland formed dunes. The limestones were eroded by the sea and honeycombed by the downward movement of surface waters. Following the uplift came a depression bringing the land to nearly its present level.

While these are the broader features of the changes indicated in Pleistocene time it is possible that neither depression nor uplift were uniform, there may have been pauses or even comparatively brief reversals of swing; certain features of the keys and their shores suggest more than one elevation above sea level, but nowhere is there indication of a great uplift. In recent time the Everglades formed to the south of a lake larger than the present Lake Okeechobee. Sands and marls from the waste of the land and the ground-up remains of marine organisms were deposited along the shores of the mainland and keys. Pine forests covered the sand hills and the topography of the mainland assumed its present aspect. Toward the Gulf Stream the present coral reef arose on the eroded surface of the old one. Waves and currents shaped marls and sands into the atoll-like group of the Marquesas while coarser materials were piled up to form the Tortugas.

MINERAL INDUSTRIES.

BY E. H. SELLARDS.

MINERAL INDUSTRIES.

E. H. SELLARDS.

PHOSPHATE.

The phosphates of Florida are known in the market as hard rock phosphate, land pebble phosphate, and river pebble phosphate. The plate rock phosphate now being mined near Anthony is included in this report with the hard rock. The soft phosphates of which there is a considerable quantity intermixed with other phosphates is unfortunately at present not recovered.

The hard rock phosphate which is now being mined occurs along the Gulf side of the Florida peninsula from Suwanee and Columbia Counties on the north to Citrus and Hernando Counties on the south. It lies in pockets of irregular occurrence and extent and rests usually upon limestones of Vicksburg (Lower Oligocene) age. The land pebble deposits are of Pliocene age and are less irregular in their manner of occurrence than are the rock phosphate. The land pebble region at present productive lies to the south of the hard rock region, in Polk and Hillsboro Counties. River pebble phosphate is obtained from present and earlier river channels. That which has been mined has been taken chiefly from Peace River and its tributaries. The accompanying maps (pls. XI and XII) show the location of mines which were in operation during 1908.

The production of river pebble, the first of the Florida phosphates mined, increased gradually from 1888 to 1893 when the maximum production of 122,820 tons was reached. From the year 1893 to the present time there has been, with some fluctuations, a decrease in the output of river pebble, the total for 1908 being 32,950 tons. River pebble mining near Arcadia in De Soto County which has long been the center of this industry was discontinued at the close of 1908.

The discovery of hard rock phosphate was made soon after the beginning of the mining of river pebble. The first shipment of hard rock was probably made in 1890.[1] The output of hard rock phosphate has gradually increased from the beginning of mining to the present time. The total hard rock mined during 1908 was 768,011 long tons, which is a considerable increase over the production of any previous year.

---

[1] Cox, E. T., Am. Assoc. Adv. Sci. Proc. XXXIX, 260, 1891.

The first shipment of land pebble was probably made in 1891 although development began during the preceding year. In 1892 the production according to the statistics of the United States Geological Survey amounted to 21,915 tons. The rate of increase in the production of land pebble was at first gradual, but in late years has been very rapid. In 1906 the output of land pebble for the first time exceeded that of hard rock. The amount of land pebble mined during 1908 is greatly in excess of that mined during any previous year, falling little if any short of 1,150,000 long tons.

The total amount of phosphate mined in Florida during 1908 was about 1,950,961 long tons. The limit of error in this total is slight and is concerned chiefly with land pebble, the production of which may vary slightly from the amount calculated. The value of the 1908 output at the mines is little, if any, short of ten million dollars. The total amount of phosphate on hand at the close of 1908 was unusually large.

The total amount of phosphate marketed for any year may be more or less than the amount mined during that year, depending upon the amount held in storage from the preceding year and the amount remaining unsold at the close of the year. According to the statistics gathered by the U. S. Geological Survey[1] the total amount of phosphate mined in Florida during 1908 was 1,941,362 long tons. The amount marketed as given in the report was 1,692,102 long tons.

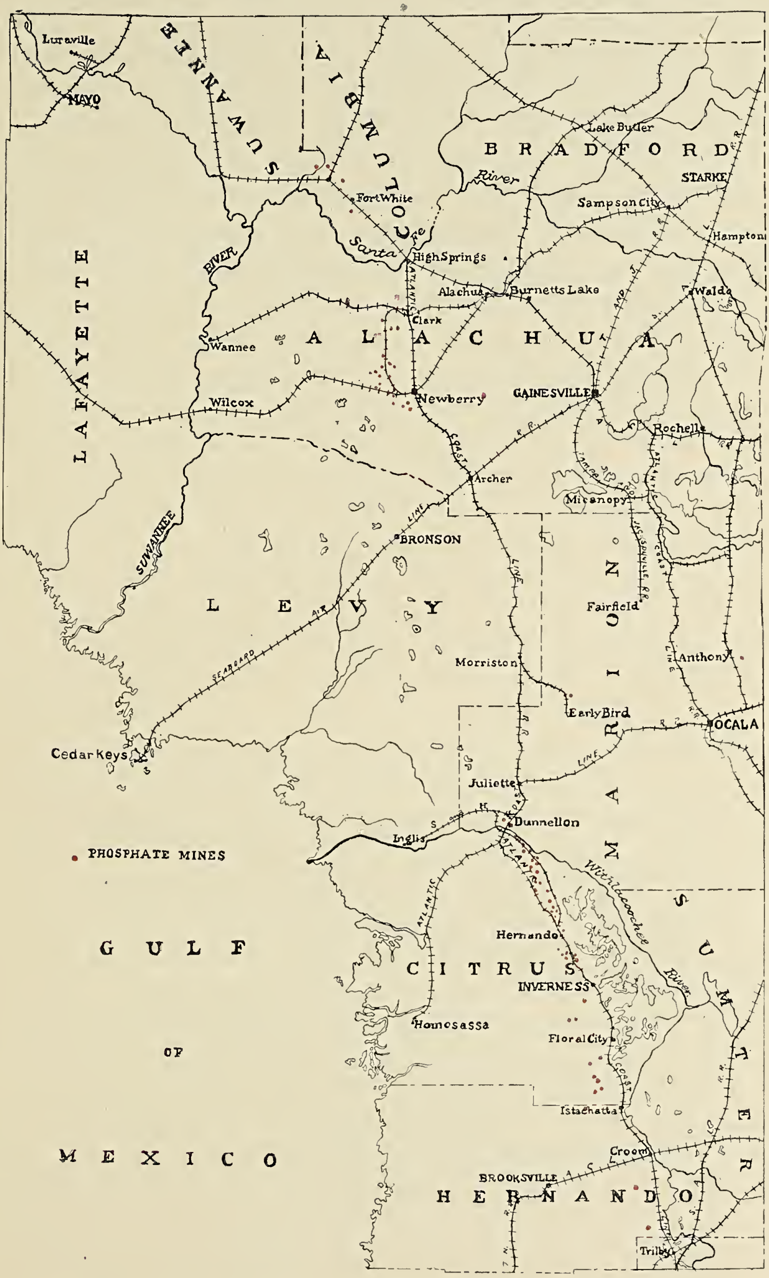
Practically all of the hard rock phosphate produced in Florida is exported, the home consumption of this grade being insignificant. During 1908 only 9,900 tons of hard rock is reported as consigned for use in the United States, 6,000 of which is reported as used in Florida. The river pebble, although not used in Florida, is used entirely within the United States, no part of the 1908 output having been exported. Of the land pebble output for 1908, about 25,000 tons is reported as having been used in Florida. Of the total amount shipped the remainder was approximately equally divided between domestic and foreign ports.

The American Fertilizer records shipment of Florida phosphates during 1908 as follows:

Hard rock, foreign shipments	631,001 tons.
Land pebble, foreign shipments	470,270 tons.
Land pebble, domestic shipments	421,781 tons.
River pebble, domestic shipments	8,468 tons.
	1,531,521 tons.

---

[1] The Production of Phosphate Rock in 1908, by F. B. VanHorn, Advance Chapter from Mineral Resources for 1908, p. 5, 1909.



MAP OF HARD ROCK PHOSPHATE MINING REGION SHOWING THE LOCATION OF MINES IN OPERATION DURING 1908.

Scale of map one inch equals 19 miles.

The total amount of phosphate marketed from the United States during 1908 was according to the reports of the United States Geological Survey 2,386,138 long tons. Of this amount Florida produced 70.9 per cent. Other states contributing to this total were: Tennessee, 19.1 per cent; South Carolina, 9.4 per cent; Arkansas, Idaho, Utah and Wyoming combined .6 of one per cent. Of the world's output of phosphate rock Florida is now producing approximately one-third.

During 1906 the demand for phosphate exceeded the ready supply, and prices advanced accordingly. Florida hard rock phosphate which during the preceding year had sold for $7.50 to $7.75 per ton F. O. B. at ports advanced to $8 and $9 per ton. The shortage in the supply of hard rock centered attention upon the land pebble which sold by the close of 1906 as high as $6 per ton F. O. B. at ports. The high prices of 1906 were maintained during 1907, Florida hard rock selling during this year at $10.25 to $10.50 at ports, while land pebble was quoted by the close of 1907 as high as $7.50 to $7.75 F. O. B. at ports. During 1908 the demand for phosphate became less active and the price declined, land pebble being quoted at the close of the year at $4.25 to $4.50 per ton and hard rock at $10 to $10.25 F. O. B. at ports. The quotations for June, 1909, as given by The Engineering and Mining Journal are: Hard rock, $7.50 to $8.00; land pebble, $3.75 to $4.00, F. O. B. at ports.

The Florida phosphates are sold ordinarily under guaranteed analysis. The guarantee which the producers are able to give varies with the kind of phosphate mined and to some extent with individual deposits and methods of mining. Most of the hard rock is sold under a guarantee that the rock will average 77 per cent tricalcium phosphate ("bone phosphate of lime" of commerce); that iron and alumina combined will not exceed 3 per cent; and that the moisture will not exceed 3 per cent. Much of the land pebble is sold under a guarantee of 68 per cent tricalcium phosphate; iron and alumina combined not to exceed 3.5 per cent to 4 per cent; and moisture not to exceed 3 per cent. Some of the producers of land pebble, however, are now able to guarantee as high as 72 per cent of tricalcium phosphate; river pebble is sold ordinarily under a guarantee of 60 per cent tricalcium phosphate, iron and alumina not to exceed 3 per cent; and moisture not to exceed 3 per cent.

The aluminous material such as clays which are associated with the phosphates are removed chiefly by washing and afterwards to some extent by drying. Thorough washing is effected by means of log washers. The clay being flooded out by water as the phosphate passes through the washer. During the process of drying the clay adhering to the phosphate is somewhat further reduced.

To reduce the moisture to the required 3 per cent the producers of land pebble phosphate use mechanical dryers entirely. While there are several types of these dryers, all consist of a rotary cylinder. Heated air and gases of combustion are made to pass through the cylinder from a furnace in front. The wet phosphate rock is fed automatically into the cylinder and by means of varying types of shelving riveted to the side of the cylinder is made to pass through, being repeatedly lowered through the hot gases in passing, and finally escaping at the opposite end. After leaving the cylinder the phosphate is carried by elevator to the storage bin. The fuel used is coal, wood or crude petroleum.

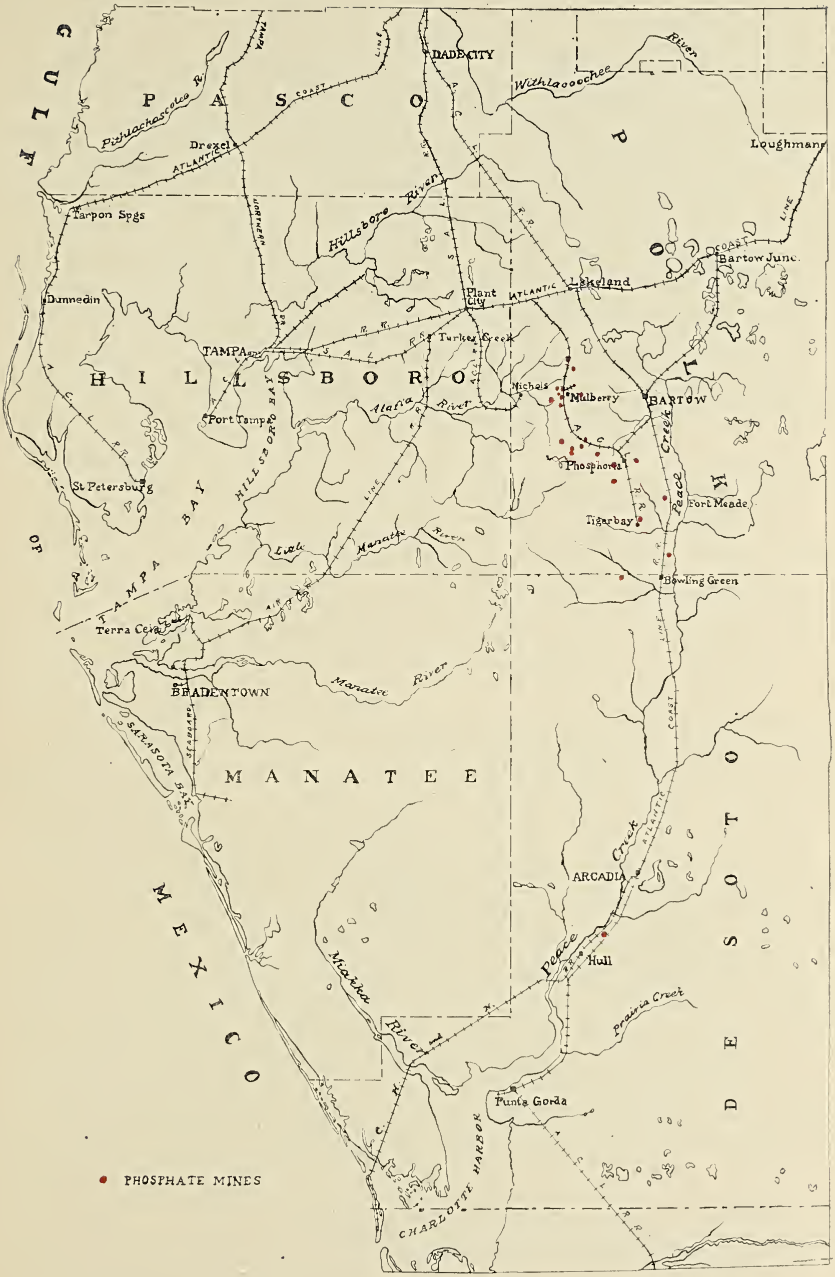
The excess of moisture from the hard rock phosphate in Florida during the early years of mining was removed entirely by kiln burning, a process still in use by many operators. For this purpose the phosphate is placed on ricks of wood. The wood is then fired and the phosphate partly smothering the flame permits slow burning, gradual spread of the heat, the phosphate being more or less uniformly dried. More recently, with the growing scarcity of wood in the hard rock section, several of the large producers have installed mechanical dryers similar in character to those used by the land pebble producers.

Phosphates of varying grades and varieties occur in Florida over a large territory extending from some distance west of the Apalachicola River east to St. Johns River, and south somewhat beyond the Caloosahatchee River. The section of high grade phosphate at present productive shown in the maps of plates XI and XII, is included within, but comprises a very small part of this area. Phosphates mostly of relatively low grade are known at many localities beyond the limits of the productive section. A detailed report must await further investigations. A few of the localities, however, may be mentioned at this time.

River pebble in varying amounts occurs along most of the streams flowing from the phosphate sections of the State.

Hard rock phosphate, aside from the area mapped occurs in Lafayette, Taylor and Jefferson Counties, various samples having been reported from these localities. Analyses of these samples may be found in the successive reports of the State Chemist of Florida.

The calcareous sand of the Alum Bluff formation found at Rock Bluff, Alum Bluff and many intermediate localities along the Apalachicola River and its tributaries, contains ordinarily a trace of phosphate and in some localities is more highly phosphatic. A few samples from this section, and coming probably from this formation, have been received which contain as much as 44 to 64 per cent of tricalcium phosphate, and phosphates of a somewhat higher grade are reported to



MAP OF LAND AND RIVER PEBBLE PHOSPHATE MINING REGION SHOWING THE LOCATION OF MINES IN OPERATION DURING 1908.

Scale of map one inch equals 19 miles.

occur. The matrix of the phosphates of this formation is either sand or lime.

Calcareous and phosphatic sandstone inclusions are found in and beneath the red sands and sandy clays of Leon, Jefferson and Gadsden Counties. The sandstone fragments in these deposits probably represent inclusions from an older formation washed in from the near by land surface during the deposition of the sands and clays. This calcareous or phosphatic sandstone probably representing the Alum Bluff sands may be seen apparently in position in the Georgia, Florida and Alabama Railroad cut about two miles northwest of Tallahassee, and at the "basin" or sink at Lake Miccosukee. Very similar phosphatic material occurring in "Nigger Sink" near Alachua, described by Johnson, is regarded by Dall as representing the Hawthorne beds at that locality. Sandstone of similar character occurs at Alachua Sink near Gainesville.

In Wakulla County low grade phosphates have been reported by several observers. In 1886, previous to the discovery of either the Peace River or the hard rock phosphates Dr. John Kost, then acting as State Geologist, reported the occurrence of low grade phosphate in Wakulla County near Sopchoppy and along the Ocklocknee River. The matrix at this locality is likewise a sandstone, and is probably also of the Alum Bluff formation.

Phosphate in a gray coarse sandstone matrix occurs in Hamilton County, having been mined to a limited extent near the Allapaha River, west of Jasper. River pebble occurs in this county north of Jennings, near the Georgia-Florida state line.

Certain low grade phosphates near Hawthorne are reported to have been the first of the Florida phosphates to be used as a fertilizer. Samples of a limestone at this locality used as a building rock were found to contain in some cases as much as 16.07 per cent of phosphoric acid[1] (equivalent to 35.09 per cent of tricalcium phosphate). During 1883 or 1884 pebble phosphates occurring about one mile west of this quarry were ground to form a fertilizer by Dr. C. A. Simmons.

Phosphatic limestone occurs at the Devil's Millhopper near Gainesville. The exposure at this locality has usually been referred to the Hawthorne formation.

In a deep sink about three miles southeast of Brooker in Bradford County thirty-nine feet of matrix containing varying amounts of pebble phosphate lie beneath thirty-seven feet of shell marl, and covered slope. The detailed section at this sink is as follows:

---

[1] Smith. Cotton Production Report, 10th Census of the United States, 1880, pt. II, p. 194, 1884. Hawes. Proc. U. S. National Museum for 1882, pp. 46-48, 1883.

Section at the sink three miles southeast of Brooker.

13.	Covered and sloping	14	feet.
12.	Cream or light colored marl full of small shells	23½	feet.
11.	Yellowish sand matrix holding black pebble phosphate	5	feet.
10.	Sandy limestone ledge with fossils	¾	foot.
9.	Yellow sand matrix with fossil plants and pebble phosphate	4	feet.
8.	Concretionary limestone ledge	2¼	feet.
7.	Steel gray colored sand-clay oxidizing yellow	5	feet.
6.	Concretionary ledge containing pebble phosphate	1	foot.
5.	Sandy matrix with pebble phosphate	4	feet.
4.	Concretionary ledge	5	feet.
3.	Clayey matrix holding black pebble phosphate	5	feet.
2.	Concretionary ledge	1½	feet.
1.	Clayey matrix holding black pebble phosphate	4	feet.
	Total depth to the water's edge	75	feet.

The sink at which this section is made is circular in outline and is possibly 200 feet across. The depth of the sink to water level is 75 feet; the depth below water level has not been determined, although it is reported to be more than 100 feet. With the exception of the entrance of a small stream from the east the sides are almost perpendicular. This stream has cut its channel through to the hard ledge of stratum No. 4, over which it forms a waterfall. Strata numbers one to four of the section stand vertical entirely around the sink. The sands of numbers five to eight weather brownish in color, forming a conspicuous band surrounding the sink, except where cut across by the stream. The sands of number nine and eleven slope slightly from the lack of supporting ledges. The marl, number twelve, stands vertical or nearly so.

From its considerable thickness the phosphate pebble bearing formation of this section may be expected to be found underlying a considerable area in this part of the State. The pebble phosphate in this exposure is of a brownish color differing from the land pebble phosphate of south Florida and resembling in this respect the river pebble. This formation is without doubt the matrix from which have been washed the phosphates of Black Creek and other tributaries entering the St. Johns River.

LOSS OF PHOSPHATE IN MINING.

That there is considerable loss of phosphate in mining is well known. Practically all deposits contain along with other material more or less phosphate in a soft or pulverulent condition. Under present methods of treatment this "soft" phosphate is necessarily lost in the process of washing, being carried to the dump along with the

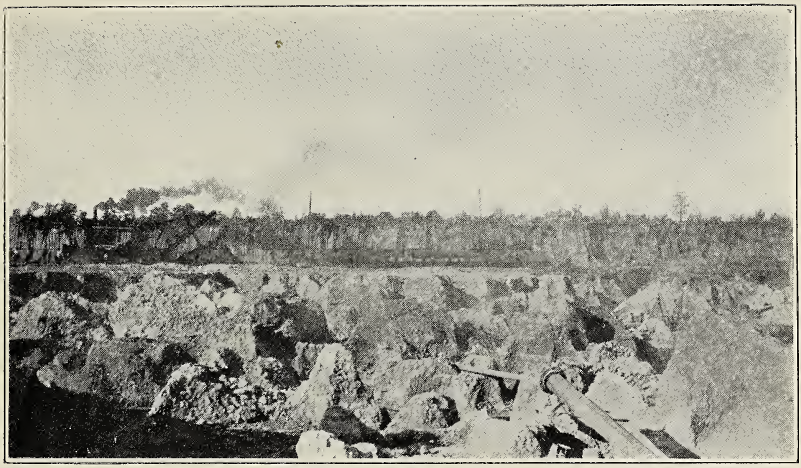


Fig. 1.—PLATE ROCK PHOSPHATE MINING, ANTHONY, MARION COUNTY. THE IRREGULAR TOP SURFACE OF THE LIMESTONE AFTER THE PHOSPHATE HAS BEEN REMOVED IS SEEN IN THE FOREGROUND.

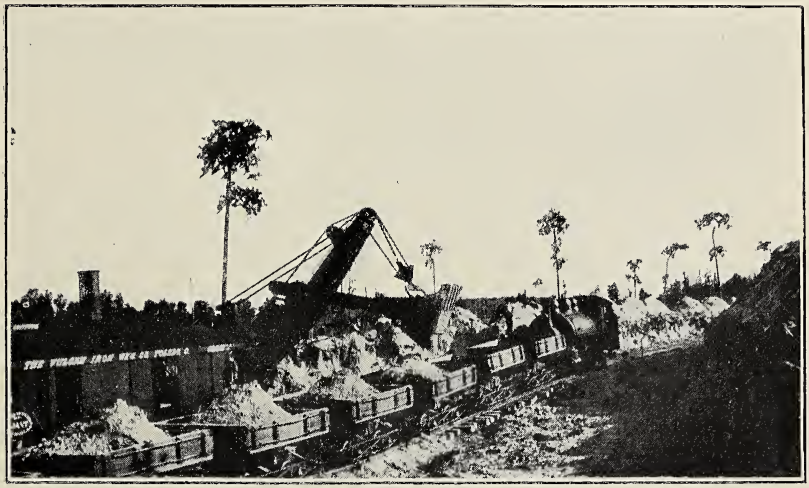


Fig. 2.—REMOVING OVERBURDEN, LAND PEBBLE PHOSPHATE, MULBERRY.

sand, clay and other constituents of the matrix. The amount of phosphate thus discarded may be expected to vary with different deposits and under different conditions. After reaching the dump there is also more or less mechanical separation, so that samples taken from one part of a dump may be found much richer in phosphate than from some other part of the same dump. Samples taken somewhat at random from the phosphate dumps in the hard rock region gave the following: No. 1 is from mine No. 5, of the Cummer Lumber Company, Newberry, Fla. No. 2 is from Camp Phosphate Mining Co., five miles southeast of Dunnellon, Fla. Analyses in the office of the State Chemist.

	No. 1.	No. 2.
Total phosphoric acid (P_2O_5)	9.99	12.14
Equivalent to tricalcium phosphate	21.81	26.50

A sample of floats from the dump in the land pebble section gave the following analysis. This sample was taken from the dump of the Charleston Mining and Manufacturing Company at Fort Meade, Fla. Analysis in the office of the State Chemist.

Total phosphoric acid	11.47
Equivalent to tricalcium phosphate	25.04

Analyses made by Mr. P. Jumeau, manager of the plant, of two samples from the wash of the plate rock phosphate mine operating at Anthony, Fla., gave the following results:[1]

	No. 1.	No. 2.
Silica	58.95	60.10
Iron and alumina	11.70	11.20
Calcium phosphate	27.92	26.80
Not accounted for	1.43	1.90

Mr. Jumeau estimates that in this plant approximately four tons of matrix is handled in order to obtain one ton of high grade rock phosphate (77 per cent). In other words of the material taken from the pit three-fourths carrying about 27 per cent calcium phosphate goes into the dump, while one-fourth carrying 77 per cent calcium phosphate is saved. It is thus seen that of the total phosphate taken from the pit in this instance fully one-half goes into the dump.

From these analyses it is apparent that a very large amount of Florida phosphate is being lost annually. Methods of reclaiming this waste or of utilizing the floats, if such can be devised, are clearly of the greatest importance to the phosphate industry, and ultimately to the agricultural interests of the country.

---

[1] Composition des Gisements de Phosphate de Chaux des Etats-Unis, P. Jumeau, Paris, 1906.

With the extension of agriculture necessary to support increased population, together with the progressive exhaustion of the new and naturally rich soils there arises increased demands upon the phosphate supply. At the present time this demand is coming chiefly from the older countries of Europe, and the phosphate now produced is largely exported. The time is not far distant, however, when an equally strong demand will come from the exhausted soils of our own country.

CLAYS.

PLASTIC KAOLIN OR BALL CLAY.

The ball clays or plastic kaolins are among the most important clay products of the State. The Florida ball clays are white burning, highly refractionary and very plastic. Ries suggests that they be known as plastic kaolins.[1] The ball clays are used largely to mix with the less plastic clays to bring up the grade of plasticity. This clay as it occurs in Florida is intimately mixed with coarse sand. There is usually an overburden of a few feet of sand. This is loosened by force pumps, and is removed by suction pumps. The presence of the sand in the clay necessitates washing, after which the clay is allowed to collect in the settling basins. It is then compressed into cakes by which excess of water is removed. The cakes are then broken up and either air-dried or artificially dried for shipment. The deposits at present known lie in the central peninsular section from Putnam to Polk Counties. Putnam County deposits occur in and about Edgar and McMeekin. Deposits have been located in Lake County along the Palatlakaha (Palalakaha) River.[2] Ball clay has also been reported from near Bartow Junction in Polk County, which is apparently the locality farthest south at which these deposits have been found. The formation holding the ball clay has many resemblances to the coarse or "Altamaha grit" phase of the red sands covering a large part of western Florida and described in the earlier pages of this report as the Lafayette formation. (Pages 141-145.)

At Edgar 4 to 10 feet of loose sand lies above the kaolin bearing sand. This top sand is coarse, containing siliceous pebbles up to one-third of an inch across. The larger pebbles are flattened and all are rounded. The kaolin bearing sands beneath are gray in color although the weathered surface is sometimes slightly iron stained. They are said to have a total thickness of 30 feet or more. These sands are distinctly cross bedded, especially the upper five feet as seen in the pit at Edgar.

---

[1] Clays, Their Occurrence, Properties and Uses. 1906, p. 165.

[2] Seventeenth Ann. Reprt. U. S. Geol. Surv., pt. iii (cont.) 1895-96, p. 872.

They are underlain by a sticky blue clay. It is reported that beneath the blue clay a fullers earth occurs, and that this in turn passes at the depth of about 70 feet into a scarcely indurated shell stratum. A well put down by the Edgar Plastic Kaolin Company is reported to have passed through coarse superficial sand, 10 feet; kaolin bearing sands 30 or more feet; sticky blue clay with fullers earth beneath about 40 feet; scarcely indurated shell stratum, 20 feet; the well terminated on a hard limestone rock at the depth of 90 feet.

The kaolin in Lake County occurs under conditions similar to those found in Putnam County. The superficial sands here as at the Edgar mines are coarse and contain white siliceous pebbles. The kaolin bearing sands are gray in color except where stained red with iron. They are separated by a seeming unconformity from the loose sands above. At places a small amount of mica is found in the kaolin sands which is screened out in the process of washing. Sands of similar character but with a larger proportion of iron occur in the vicinity of Leesburg and Hawthorne and are used for road materials.

Four plants were engaged in mining plastic kaolin during 1908. Two of these, under the management of the Edgar Plastic Kaolin Co., are located at Edgar in Putnam County. The two other plants are the Richmond Kaolin Co., of Richmond, Florida, and the Florida Clay Co., of Yalaha, Florida, both in Lake County.

BRICK MAKING CLAYS.

The surface deposits of north and central Florida contain many clay beds. These clay deposits are often of local extent, and usually of variable character. Sands and sandy clays make up the surface deposit over much of the northern tier of counties west of the Suwanee River. Less well defined clays of local extent and variable character occur widely in peninsular Florida. For the purpose of brick making a clay should mold easily, and burn hard at a low temperature without excessive loss from warping and cracking. Such beds as occur in Florida suitable for brick making are confined to no particular geological horizon. The total number of common brick made in Florida during 1907 as reported by the United States Geological Survey was 51,779,000 valued at $343,704.

PEAT.

Investigations of the peat deposits of the State made during the past year have proven the presence of very extensive peat deposits widely distributed throughout the State. The fuel tests made in this connection in the fuel testing laboratory of the United States Geological Survey prove that the Florida peats are well up to the average in fuel value. Both the details of the occurrence of the peat and the analyses of samples will accompany the report on peat when completed.

When it is remembered that in northern Europe more than 10 million tons of peat are prepared and used for fuel annually,[1] it will scarcely be doubted that the large deposits in Florida will ultimately be used either for fuel or for other purposes for which peat with the improved processes of treatment may be adapted.

DIATOMACEOUS EARTH.

Diatomaceous earth consists of the tests of certain small plants known as diatoms. When pure it is a white powdery looking substance. As it occurs in nature it contains often more or less impurities. The diatoms themselves are minute in size and are visible only by the aid of the microscope. They are aquatic in habit and live in both salt and fresh water, and are particularly abundant in fresh water ponds. These minute plants secrete during life a siliceous covering or test. After the death of the plant the test falls to the bottom. The accumulation of these tests forms in time the deposits known as diatomaceous earth.

Diatoms seem to have been particularly abundant during the Tertiary period, large deposits formed during that time having been found in various parts of the world, especially in New Mexico, Nevada, California, and Oregon, as well as in Europe.

The deposits found in Florida were formed in fresh water ponds and are of comparatively recent date. A deposit near Eustis which has been worked to some extent is in general appearance not unlike other peat bogs of that section. The diatomaceous earth is in fact intimately mixed with the peat or muck and the material as taken from the bog has the appearance of peat of a grayish color. The method of treatment is to burn out the carbonaceous matter, the siliceous material remaining as a very fine, white powder. The deposit of peat in this bog according to soundings made by Dr. R. M. Harper has a thickness of twenty or more feet. Aside from the tests one observes in a mount of this material more or less silica resulting possibly from the silica contained originally in the stems and leaves of grasses.

Infusorial earth is a term often used in commerce interchangeable with diatomaceous earth. Tripoli has frequently been used in America to apply to a material which serves a similar purpose obtained from a bed of decomposed flint or chert.

---

[1] Davis, C. A. U. S. Geol. Surv. Bull. 379, p. 63, 1908.

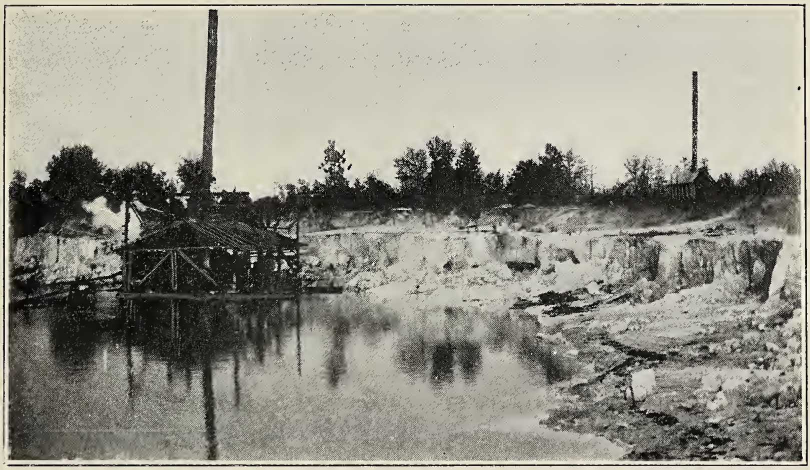


Fig. 1.—PLASTIC KAOLIN MINE, EDGAR, PUTNAM COUNTY.

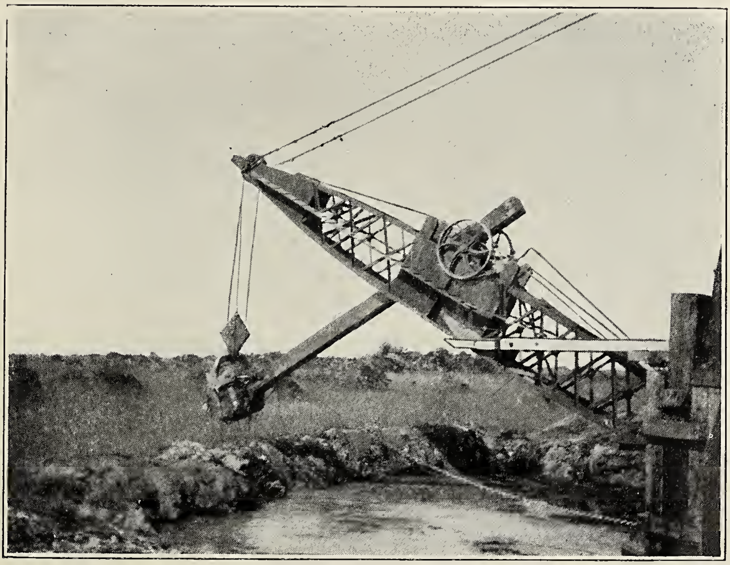


Photo by Matson.

Fig. 2.—DREDGE EXCAVATING PEAT, NORTH CANAL, NEAR FORT LAUDERDALE.

Diatomaceous earth is used largely as a polishing powder for which its hardness and fineness render it particularly applicable. It is also used in some scouring soaps, and to some extent in the manufacture of dynamite as an absorbent for nitroglycerine. It is a good nonconductor of heat and hence is valuable for packing steam pipes, and to some extent for fire-proof material in general, including building stone.

LIME AND GROUND LIMESTONE.

Lime or "quick lime" is chemically an oxide of calcium or of calcium and magnesium. It is made ordinarily by burning limestone, although shells and other calcium carbonates may be used for the same purpose. In the process of burning the carbon dioxide of the limestone is driven off leaving the oxide as lime.

The Florida Lime Co. of Ocala in addition to the manufacture of lime has during the past year installed machinery for grinding the natural limestone. The limestone thus ground is designed for application to the soil to correct acidity.[1] Calcareous rocks and shell deposits suitable for grinding for this purpose are widely distributed in the State as indicated in the paper on Stratigraphic Geology in the preceding pages of this report. Limestones occur at or near the surface locally in Walton, Holmes, Jackson and the northern part of Washington Counties. Limestones of the Vicksburg group occur extensively in central Florida (see map). The Miami oolitic limestone makes up an extensive formation running north and south from Miami and forming the east border of the Everglades. The Apalachicola group including some compact limestones occurs extensively in parts of west Florida. The marls are usually of local occurrence and are restricted to no part of the State. Recent shell deposits are abundant on the coast and along some of the rivers.

SAND-LIME BRICK.

Five plants have been engaged during all or a part of the year in the manufacture of sand-lime brick. These are as follows: Seminole Pressed Brick Company, Jacksonville; The Florida White Pressed Brick Company, Jacksonville; The Bond Sandstone Brick Company, Lake Helen; Plant City Granite Brick Company, Plant City; and Florida Brick Company, Live Oak. The last named plant closed early in 1908. The total number of sand-lime brick made in Florida during 1908 as reported by the United States Geological Survey was 21,014,000, valued at $117,040.

---

[1] Material for correcting soil acidity. Press bulletin No. 78, Fla. Agri. Exp. Station, by A. W. Blair. Also Bulletin No. 93, p. 52, 1908.

BUILDING STONE.

The building stone of the State consists chiefly of limestones, of which several varieties occur.

Coquina:—The coquina rock of Anastasia Island near St. Augustine has been known as a building stone for more than three hundred years. This coquina was in fact the first stone used for building purposes in America, its use having begun with the settlement of St. Augustine about 1565. Coquina (pl. VII, fig. 2) consists of a mass of shells of varying size or fragments of shells cemented together ordinarily by calcium carbonate. A small admixture of sand is in some instances included with the shells. When first exposed the mass of shells is imperfectly cemented and the rock is readily cut into blocks of the desired size. Upon exposure, however, the moisture contained in the interstices of the rock evaporates and in doing so deposits the calcium carbonate which it held in solution thus firmly cementing the shell mass into a firm rock. Thus indurated the resisting qualities of the rock are good. The shells from this formation have been extensively used with concrete in the construction of modern buildings at St. Augustine. Aside from its occurrence on Anastasia Island coquina is found at many other points along both the east and the west side of the peninsula.

The Vicksburg Limestone:—The Vicksburg limestone has been used to some extent for building purposes. This is true especially of that phase of the Vicksburg known as the "chimney rock" described in the preceding pages as the Marianna and the Peninsular limestones. The chimney rock is when first taken from the ground very soft and can be easily sawed into blocks. Upon exposure to the air it hardens, due, as in the case of the coquina, to the evaporation of moisture from the interstices of the rock. The chimney rock was early used both in Alabama and Florida for the construction of chimneys and to some extent for building purposes.

Locally the Vicksburg and some of the other limestones in Florida become very close grained and compact. In this condition the limestone is hard, approaching marble in appearance. Although little used this phase of the limestone formation is capable of producing a good building stone.

Miami Oolite:—The Miami oolitic limestone has been used successfully as a building stone at Miami. This formation extends for some distance along the eastern border of the Everglades north and south from Miami (see map). As in the case of the other limestone when first taken from the quarry it is relatively soft and easily worked, but hardens upon exposure. The hotel Halcyon Hall and some other buildings at Miami are constructed of this rock.

MATERIALS FOR MORTAR AND CONCRETE.

Sands either siliceous or calcareous occur in practically all parts of Florida. Sands for mortar in order to give the best results should be angular in shape. This is due to the fact that a rough and angular sand grain permits a better bonding power than a smooth and spherical grain. The size of the sand grains also has a bearing on its qualities as a mortar sand. Coarse sand has a smaller surface area in proportion to volume than has fine sand. In order to obtain the best results each grain of sand in a mortar should be thoroughly coated with cement, and it appears probable that the coarse sand owing to its smaller proportion of surface area becomes better coated than a fine sand. While a coarse sand is preferable to a fine sand, for certain purposes it may be desirable to have a mixture of coarse and fine grains. The cement used in the mortar must be sufficient to completely fill all voids existing in the sand. The relative proportion of voids may be reduced by the use of a mixture of coarse and fine sands. Such a mixture of sands permits the use of a relatively smaller amount of cement, and is apparently without detriment to the resulting mortar. Sand is used along with lime in the manufacture of sandlime brick; and with cement in the preparation of artificial stone or building blocks.

The sands most frequently used for mortar are siliceous. It appears, however, from various tests that calcareous sands are in no way inferior.[1] In addition to the natural sands ground rock may also be used. A small amount of clay, not exceeding ten to thirty per cent., is said not to weaken the cement. The presence of humus or peaty matter, or an excess of clay as well as mineral particles of any kind subject to decay, must be guarded against.

The illustrations of plate XV show the prevailing shape of the sand grains from a number of localities in Florida. The relative size of the sand grains is also indicated, all of the illustrations having been drawn to the same scale.

The materials in Florida suitable for concrete consist chiefly of shell deposits and some compact limestones and of flint rock which may be crushed for the purpose.

---

[1] Cement and Concrete, Sabin, p. 170, 1907.

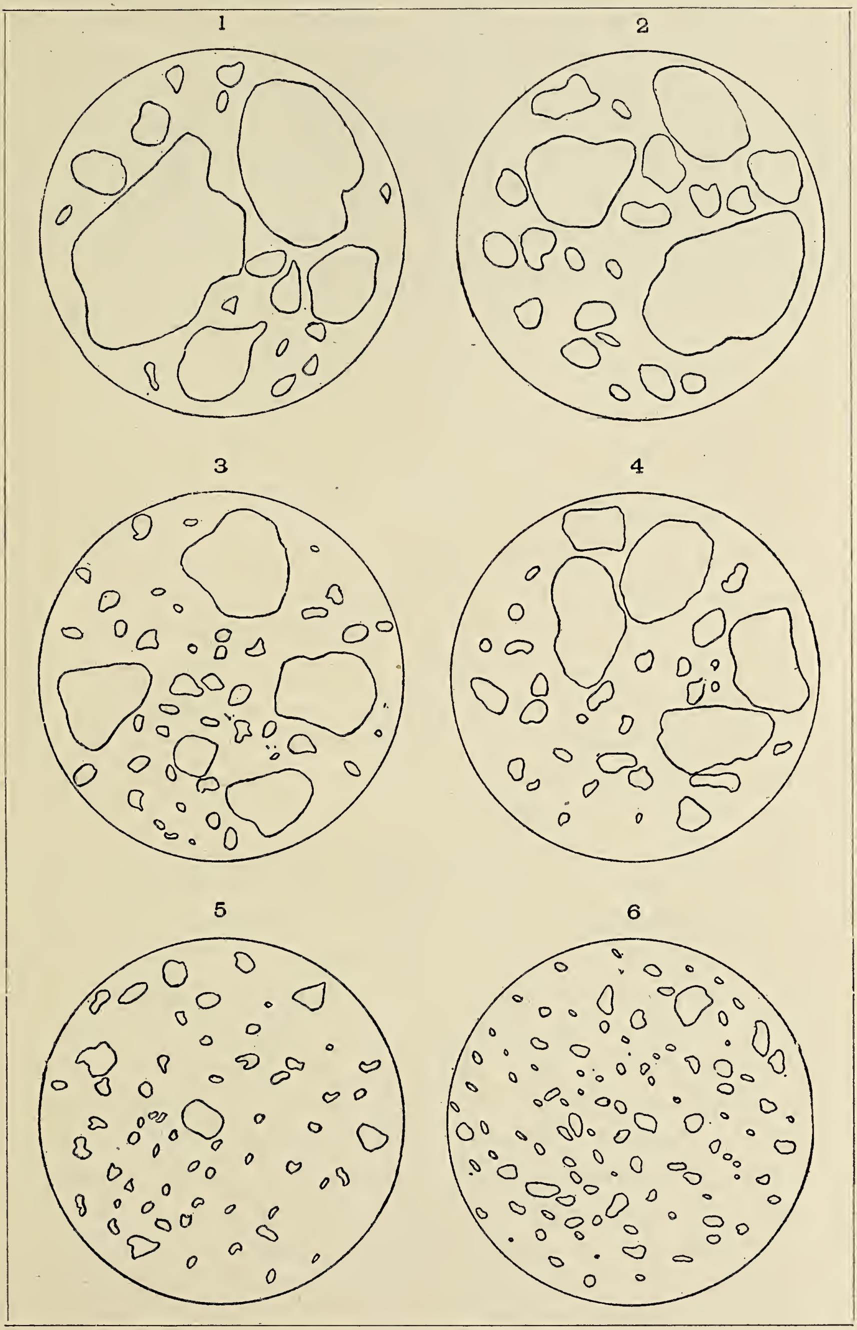
Flint is chemically an oxide of silica SiO_2 with more or less accompanying impurities. It is a variety of the mineral quartz, occurring massive and non-crystallized or more accurately very imperfectly crystallized (cryptocrystalline). The term chert is often used interchangeably with flint. Properly chert is an impure flint or flinty rock. Flint and chert are lacking in cleavage. They break, as do the other varieties of quartz, with conchoidal fracture. A flint rock when crushed breaks into sharp cornered pieces of varying size.

Properties:—The mineral quartz, of which flint is a variety, has a hardness of seven on a scale in which the hardest mineral diamond, is ten. The varieties of quartz vary in hardness slightly according to the impurities that they contain. Silica is one of the least soluble of minerals and among the most resistant to decay.

Occurrence of Flint and Chert in Florida:—Flint and chert occur mostly as masses or "horsebacks" in the limestone formations. A good illustration of the manner of occurrence may be seen in phosphate pits or in some of the pits of the Florida Lime Co., at Ocala. In some of the sinks on Thompson's farm two miles east of Sumterville will be seen flint masses exposed by the natural decay of the limestone. The flint masses appear to conform to no rule as to size and extent. They may form ridges running through the limestone; or again they may occur as rounded or elongate masses. Occasionally the flint forms as a thin stratum lying horizontally. This flint bearing limestone lies at no great distance from the surface throughout all of the central peninsular section of the State from Columbia County on the north to Sumter County on the south and from the Suwanee River and the Gulf coast to east Alachua and Marion Counties. Much of the hard rock phosphate rests upon and in this flint-bearing limestone, and from the phosphate pits great quantities of the flint may be obtained. Occasional flint hills such as that crossed near Evinston and Micanopy stand out as evidence of the resistance of flint to the weathering agencies, the surrounding limestone having disappeared through erosion. This flint lies chiefly within the Vicksburg limestones (see map). It is not to be inferred, however, that no other Florida formations contain silica. On the contrary, many of the formations are highly siliceous. The Vicksburg limestones are, however, the chief flint-bearing formations of Florida.

Origin of the Flint in the Vicksburg Limestones:—The flint occurs as has been stated, in masses irregularly distributed through the limestone. Well drillers can bear witness to the frequency of flints and to their distribution through the limestone to a great depth. The flint masses were clearly not present in the limestone as originally formed.

FLORIDA GEOLOGICAL SURVEY. SECOND ANNUAL REPORT. PL. XV.



FIGS. 1-6.—FLORIDA SANDS. 1.—Alapaha River, Hamilton County. 2.—Lake Weir, Marion County. 3.—Glendale, Lake County. 4.—Suwanee River, Suwanee County. 5.—Cedar Keys, Levy County. 6.—Crystal River, Citrus County. All figures 4 1-3 times natural size.

This formation when not affected by chemical change consists typically of a mass of calcareous shells of varying size from minute foraminifera to larger bivalves and gastropods with which is interbedded coral and other fossils, along with a limited amount of siliceous material supplied principally by sponge spicules. Originally, without doubt the limestone consisted largely of the remains of these calcareous shells, the flint masses having been subsequently deposited through the agency of underground water. Water in its round of circulation through surface and deeper formations takes silica as well as other substances into solution. In the course of its circulation through the limestone the silica in solution in the water replaces the calcium carbonate of the limestone. The direct evidence that the flint masses are formed by the replacement process is to be had from the examination of a piece of flint. In this it will be seen that the foraminifera and other shells which were originally calcareous have been changed to silica. The replacement process is by no means confined to the formation of flints. Chemical changes are constantly going on among the minerals making up the rock formations, and replacement of one mineral by another is one of the important phases of chemical change.

The compact and partly crystallized limestones which occur locally as previously mentioned under Building Stone is probably due to a somewhat similar process. The change in the case of the limestone involves a rearrangement of the constituent molecules, resulting in a harder and more compact rock.

Shell deposits, both recent and fossil, are numerous in the State. The use of shell from the coquina rock for building purposes has already been mentioned. Among notable buildings from these shells may be mentioned the Ponce de Leon hotel at St. Augustine. The calcareous shell mass as found at this locality may contain a small admixture of siliceous sand blown in by the winds. Recent shell deposits occur at many places along both the Atlantic and the Gulf coasts. Shell mounds piled up by the Indians are likewise numerous on and near the coast. Some occur inland also, those of the St. Johns River from Jacksonville to Sanford being notable examples. Deposits of fossil shells are likewise numerous, although as a rule less free from impurities than are the accumulations of recent shells. The localities at which many shell exposures occur have been mentioned in the preceding pages of this report.

MINERALS NEW TO THE STATE.

MALACHITE.

The mineral malachite, a copper carbonate ($CuCO_3$, $Cu(OH)_2$), has been reported from the State during the past year, a sample having been submitted to the State Chemist for analysis. The mineral is reported to have been obtained from a well at the depth of about 86 feet. The well is on the place of Mr. Arch Johnson, in Suwanee County, about 5 miles southeast of Dowling Park, station, on Sec. 26, T. 3 S., R. 11 E.

THE FULLERS EARTH DEPOSITS OF GADSDEN COUNTY, FLORIDA.

WITH NOTES ON SIMILAR DEPOSITS FOUND ELSEWHERE IN THE STATE.

BY E. H. SELLARDS AND HERMAN GUNTER.

PREFACE.

Field work in the preparation of this report was begun in the early fall of 1908. At that time it was expected that the fullers earth deposits of the State as a whole would be reported upon in a single bulletin. It has been found, however, that the fullers earth deposits are much more widely extended than was previously supposed, and it is not advisable to delay publication until the entire State has been covered. Fullers earth was first discovered and mined in America in Gadsden County, Florida. This section, therefore, formed a natural starting point in the study of fullers earth, and as the field work in this county is now nearing completion this preliminary report is issued in order that the results obtained may be given promptly to the public. This paper may, therefore, be regarded as a report of progress in the study of the fullers earth deposits of Florida.

The Survey is indebted to those engaged in mining fullers earth for the uniform courtesy that has been invariably extended in making available all possible information regarding these deposits as shown by their respective mining operations. To the many citizens and land owners who have assisted with general information the thanks of the Survey are also due. The soil survey map of Gadsden County issued by the United States Department of Agriculture has been of great assistance. The location of railroads, streams and other natural features on the accompanying map of Gadsden County is taken from this soil map. The notes previously made on the Gadsden County fullers earth by T. W. Vaughan have also been of service in this study.[1] Several analyses have been made in connection with the preparation of this report by the State Chemist. These are credited in the text.

The features of this paper which will probably be found of most practical value in the hands of land owners and of others interested in fullers earth may be summarized as follows:

(1.) A guide rock associated with and indicating the presence of fullers earth is recognized and described. This guide rock consists of a greenish to gray or yellowish sand or sandstone. This sandstone is, in Gadsden County, a part of the fullers earth series and its presence in this section indicates the place of the fullers earth. This rock is in places indurated and resistant to decay. It thus often stands out and is exposed where the fullers earth itself is entirely covered.

---

[1] Mineral Resources, U. S. Geol. Survey for 1901, pp. 922-934, 1902; Bulletin U. S. Geol. Survey, 213, pp. 392-399, 1903.

(2.) The localities in Gadsden County at which fullers earth was observed to occur are indicated on the accompanying map (pl. xviii). In addition, fullers earth may be expected to be found exposed at many intermediate places along the streams in this county. It has also been found at numerous other localities in the State as indicated in the text.

Aside from the location of fullers earth the investigations have contributed materially toward an understanding of the geology of a part of Florida, and have thus added to the sum total of the knowledge regarding the geology of the State.

THE FULLERS EARTH DEPOSITS OF GADSDEN COUNTY.

WITH NOTES ON SIMILAR DEPOSITS FOUND ELSEWHERE IN THE STATE.

E. H. SELLARDS AND HERMAN GUNTER.

INTRODUCTION.

Fullers earth is a clay differing from other clays chiefly in that it is light and porous, and possesses in a high degree the quality of absorbing greasy substances. This earth was formerly used by fullers to remove greasy spots from cloth, from which usage it receives its name of fullers earth.

The fullers earth of Gadsden County occurs as strata interbedded between sandstone or bluish to yellowish sands, varying in places to calcareous and shell bearing marls. The fullers earth itself rarely contains fossils. Both vertebrate and invertebrate remains, however, are occasionally found immediately above and below the fullers earth. In Manatee County fullers earth is found lying above a marl or limestone, and beneath a calcareous clay or marl.

Fullers earth, like other clays, is complex. It consists not of a single mineral, but of a variety of minerals; the mineral particles being mixed in widely varying proportions, resulting in a variable chemical and mineralogical composition. Under the microscope the Gadsden County fullers earth shows angular particles of quartz together with green double refracting particles which Merrill regards as a siliceous mineral.[1] In fullers earth from Arkansas, Merrill observed sharply angular colorless mineral particles, faintly double refracting, but lacking crystal outlines or other physical properties such as would determine their exact mineral nature. Angular particles of quartz and a few yellowish iron stained particles suggestive of residual products from decomposition of iron magnesia silicates were also recognized in this sample. The fullers earth from Surrey, England, according to the same writer, consists of extremely irregular eroded particles of a siliceous mineral and of minute colorless particles suggestive of a soda lime feldspar. Thus it may be said that while fullers earth is known to consist like most other clays of a mixture of minerals it is often difficult to make a satisfactory determination of the individual mineral constituents.

---

[1] Report of the U. S. Nat. Museum, 1899, p. 338.

Chemical Constituents:—There is a wide range in variation in the chemical constituents of different fullers earths, or fullers earth from different localities. The range of individual constituents may be inferred from the accompanying analyses.

ANALYSES OF FULLERS EARTH FROM VARIOUS LOCALITIES.

	I.	II.	III.	IV.	V.	VI.
Silica (SiO_2)	62.83	67.46	58.72	50.36	74.90	63.19
Alumina (Al_2O_3)	10.35	10.08	16.90	33.38	10.25	18.76
Ferric Oxide (Fe_2O_3)	2.45	2.49	4.00	3.31	1.75	7.05
Lime (CaO)	2.43	3.14	4.06	....	1.30	0.78
Magnesia (MgO)	3.12	4.09	2.56	....	2.30	1.68
Potash (K_2O)	0.74	....	2.11	.88	1.75	0.21
Soda (Na_2O)	0.20	....				1.50
Water (H_2O)	7.72	5.61	8.10	12.05	5.80	7.57
Moisture	6.41	6.28	2.30	....	1.70	....

No. I. From Gadsden County, Florida. U. S. Geol: Sur. 17th Ann. Rept., pt. iii (cont.), page 880.
No. II. From Decatur County, Georgia. Ibid.
No. III. From Fairburn, S. D. Ibid.
No. IV. Glacialite, Enid, Okla. G. P. Merrill, Non-metallic Minerals. U. S. Nat. Mus., Rept. for 1899, p. 337, 1901.
No. V. From Sumter, S. C., U. S. Geol. Surv., Min. Reso., 1901, p. 933, 1902.
No. VI. From Alexander, Ark. Branner, Amer. Inst. Min. Eng. Trans. XXVII, p. 62 1898. Ries, Clays, p. 465, 1906.

Physical Properties:—The most distinctive physical property of fullers earth is that of clarifying oils.

Test for Fullers Earth:—Fullers earth varies in color. That found in Florida is mostly light buff, brownish or yellowish, or olive green, gray or blue. It is not readily distinguished in general appearance from other clays. It is light and porous and when dry adheres firmly to the tongue, but some other clays are also adhesive. A practical test of fullers earth is necessary in order to determine its value. A test may be made by the use of a glass tube ½ to 1 inch in diameter and 2 to 3 feet long. To make the test, support the tube in an erect position, the lower end being plugged with asbestos fiber. The earth is powdered and packed into the tube. A mineral oil is then passed through it. If the clay is a fullers earth the oils will be more or less perfectly clarified, depending upon the quality of the earth. It is reported that a fullers earth that will clarify a mineral oil may not affect a vegetable oil, while an earth used to clarify a vegetable oil may be unsatisfactory when applied to a mineral oil. A theory of the action of fullers earth in clarifying oils is given by Porter as follows

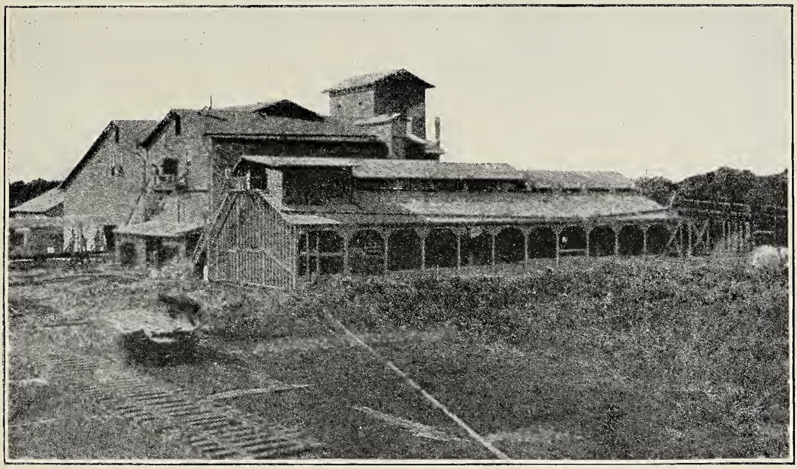


FIG. 1.—FULLERS EARTH PLANT AT ELLENTON, MANATEE COUNTY.

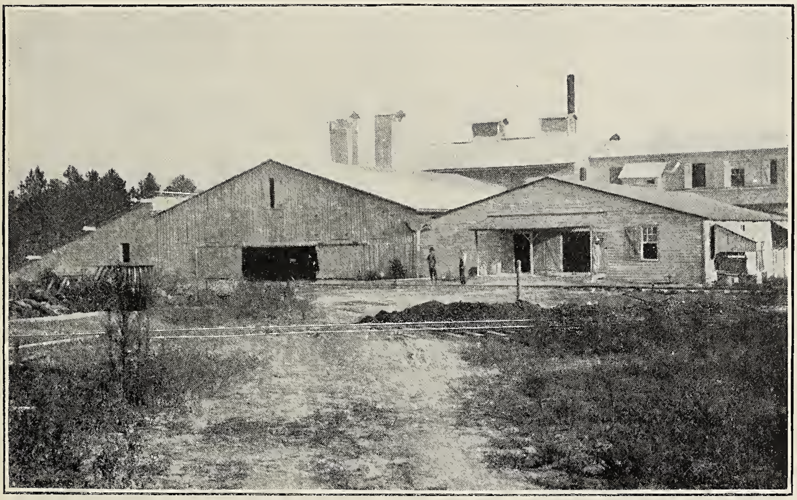


FIG. 2.—FULLERS EARTH PLANT AT QUINCY, GADSDEN COUNTY.

(U. S. Geol. Surv. Bull. 315, p. 282, 1907): "Fullers earth has for its base a series of hydrous aluminum silicates. These silicates differ in chemical composition, but are similar in that they all possess an amorphous colloidal structure. These colloidal silicates possess the power of absorbing and retaining organic coloring matter, thus bleaching oils and fats."

Uses:—The Florida fullers earth finds its chief use in filtering mineral lubricating oils. According to Day, "The common practice with these mineral oils is to dry the earth carefully, after it has been ground to 60 mesh, and run it into long cylinders, through which the crude black mineral oils are allowed to percolate very slowly. As a result the oil which comes out first is perfectly water-white in color, and markedly thinner than that which follows. The oil is allowed to continue percolating through the fullers earth until the color reaches a certain maximum shade, when the process is stopped, to be continued with a new portion of earth. The oil is recovered from the spent earth."[1] It is also used to some extent for lightening the color of cotton seed oil, and lard oil, although the English fullers earth is better for these purposes. The original use of fullers earth, that of cleaning, is now one of the minor uses. It is said to be used in the manufacture of some soaps. It is used in cleaning furs and by druggists as an absorbent.

Methods of Mining:—Originally the overburden in the Florida fullers earth mines was removed by pick and shovel. At the present time, however, the overburden is removed chiefly by steam power. The depth of overburden that can be profitably removed is determined entirely by the depth and character of the fullers earth deposit. The overburden removed in the mines which are now being worked varies from one or two, to twelve or fourteen feet. The greater part of this overburden is more or less decayed and residual in character and is readily removed. With some of the harder material, loosening by blasting becomes necessary. It is of interest to note that the fullers earth when protected by a great thickness of overburden sometimes contains irregularly distributed and residual masses of an impure clayey limestone. This was noticed in particular in the fullers earth mines at Quincy. At this place it was found that when in working back into the hill the overburden reached a thickness of twelve to fourteen feet, the fullers earth stratum contains irregular residual masses becoming more and more abundant until with an overburden of about fourteen feet the pit was abandoned.

The fullers earth itself is mined in the open pit by pick and shovel, being loosened when necessary by blasting. From the pit it is loaded by shovel into "dummy" cars and is drawn either by cable or by small engine to the plant nearby.

---

[1] U. S. Geol. Sur. 21st Ann. Rept. pt. vi, (cont.) p. 592, 1901.

At the plant the fullers earth is taken to the store house. The larger pieces are first broken by pick or sledge and the material then passed through a crusher. After passing through the crusher the material, now broken into pieces, one to two or three inches in size, is fed automatically into a drying cylinder. These cylinders which are 30 to 40 feet long and five or six feet in diameter, revolve slowly and by means of half cups set at an incline move the fullers earth forward with each revolution. A high temperature is not sought in the cylinder as used in Florida, the object being to remove the surface moisture from the clay. The fullers earth passes through the cylinder at the rate of possibly one ton an hour, each piece of clay occupying fifteen to twenty minutes in transit. The fullers earth upon dropping from the cylinders after drying is carried to a storage bin, and is there fed to the mills for grinding as needed. Two kinds of mills are in use. One of these consists of a horizontally revolving cylinder in which the earth is ground fine by a gravity ball. From this mill the ground fullers earth is carried to a jig which separates the earth into two grades of fineness. The second kind of mill, which is perhaps the mill most frequently used, grinds and delivers the earth in mixed grades. The ground material in this case is passed through bolters and separated into the grades desired for commercial purposes. After bolting, the earth is sacked for shipment and is labelled according to the degree of fineness. The grade most used in refining mineral oils is about 30-60, by which is meant fullers earth ground to a fineness which permits it to pass through a thirty mesh screen but not sufficient to permit it to pass a sixty mesh screen. The finer grades find other uses.

Production of Fullers Earth During 1908:—Three plants were engaged in mining fullers earth during 1908. These were the Owl Commercial Co., Quincy; The Southern Fullers Earth Co., Mt. Pleasant, and The Atlantic Refining Co., Ellenton, Florida. The total amount of fullers earth mined in the State during 1908 as reported to the Survey by the producers was 22,932 short tons. The product is used principally in the United States, although approximately 5 per cent of the 1908 product was exported to foreign markets.

Fullers earth in America was first discovered at Quincy, Florida. Previous to that date all of the fullers earth used in this country was imported from England. Following its discovery in Florida fullers earth deposits were located in several other States. During 1907 seven States are reported to have produced fullers earth.[1] These are in the order of the amounts produced as follows: Florida, Arkansas, Georgia, South Carolina, Massachusetts, Colorado and Texas. The total output of the United States as reported in the "Mineral Resources" for 1907 was 32,851 short tons. Of this amount Florida produces according to reports sent to the Florida Survey 24,148 short tons, or nearly three-fourths.

---

[1] Mineral Resources, U. S. Geol. Survey for 1907, p. 733, 1908.

GADSDEN COUNTY.

GEOGRAPHY AND TOPOGRAPHY.

Gadsden County lies in middle west Florida between Ocklocknee and Apalachicola Rivers. Its northern boundary is the State line, while on the south it joins Leon and Liberty Counties. The interior of the county, except where cut into by streams, forms a plateau, the top of which lies 250 to 300 feet above sea. This plateau is crossed by the Seaboard Air Line Railroad from Quincy to Mount Pleasant; by the Apalachicola Northern Railroad from Horsford to Hardaway, and by the Georgia, Florida and Alabama Railroad from Gibson to Havana. The depot of the Seaboard Air Line at Quincy is according to the railroad survey levels 260 feet above sea.[1] From Quincy to Mount Pleasant, a distance of nine miles, there is, as indicated by barometer readings, but slight change in elevation, Mount Pleasant being somewhat higher than Quincy, probably reaching at some intermediate points 300 feet. Along the line of the Apalachicola Northern Railroad, crossing the plateau from the south, elevations are found, as shown by a profile kindly furnished to the Survey by Mr. R. B. Coleman, General Manager of the Apalachicola Northern, in the vicinity of Hardaway, up to and slightly exceeding 300 feet above mean low tide.

The Apalachicola River forming the western boundary of the county has cut its channel more than 200 feet below the general plateau level. In order to reach the plateau with the minimum grade the railroad lines follow streams heading back from the river. Thus from River Junction the Seaboard Air Line and the Apalachicola Northern railroads follow Mosquito Creek and its tributaries. Even along these streams the descent is rapid, and where not cut across by streams the plateau continues with but slightly reduced elevation to the banks of the Apalachicola itself. The bluffs at Chattahoochee Landing and at Aspalaga reach a height of 175 to 180 feet above the river level within a short distance of the river. Similar elevations may be found at many intermediate points. At Rock Bluff, in Liberty County, an elevation of 200 feet above the river is reached within less than one mile of the river, and at Alum Bluff an elevation of 160 feet is found in the bluff immediately facing the river.

---

[1] Bull. U. S. Geol. Surv. 274, p. 192, 1906.

The bluff terminating the plateau at the river is continuous except where cut across by streams, through Gadsden County into Liberty County. Numerous streams tributary to the Apalachicola cut across the bluff and into the plateau, the largest of these being Mosquito Creek and Flat Creek in Gadsden County, and Sweetwater Creek in Liberty County. Many smaller streams occur and the larger streams have numerous tributaries. These streams which are fed by springs, carry an unfailing supply of clear, soft water, and cut deeply, resulting in great diversity in surface features.

The streams in the western part of Gadsden County and in the northern part of Liberty County head in a characteristic manner. Each tributary terminates in a semi-circular spring head, the descent to which is almost precipitous for 50 to 60 feet from the plateau level. Usually this slope is not too steep to retain soil and hence is thick set with a dense growth of trees. Occasionally, however, heads occur that are vertical or nearly so. The termination of these streams are spoken of locally as "steepheads." The conditions which produce these heads are as follows: The surface formations are porous and permit the rainfall to enter readily. At the depth of 50 to 60 feet the water encounters impervious clays and following these clays finds an exit as springs. These "steepheads" are thus spring heads, and these streams in fact make their way back into the plateau by the constant backward migration of the springheads. A dense growth of hard wood trees is found along the sides and in the deep valleys. Among these are found some rare plants. Chief among these may be mentioned *Tumion taxifolium* (*Torreya taxifolia*), a graceful conifer which has received from the odor arising from its foliage when bruised the unenviable common name of "stinking cedar." It has often been stated that this plant grows upon and is dependent upon the presence of the Chattahoochee limestone, a formation to be described later in this report. It is to be observed, however, that following the streams into the plateau this tree may be found up the streams far beyond the occurrence of the Chattahoochee limestone. Similarly to the south in Liberty County, this tree is found down the river below the point at which the Chattahoochee limestone finally passes beneath the river and at a stratigraphic interval at least 100 feet above that formation. Moreover at other localities, as on the Chipola River where the Chattahoochee limestone occurs, this tree has not been found. *Tumion taxifolium* has not been found at any locality other than the east bank of the Apalachicola River and apparently does not occur outside of Florida. A second related and even more restricted tree of this locality is *Taxus floridana* or the Florida yew, also unknown elsewhere.

Approaching the Ocklocknee River which forms the eastern boundary of the county one finds instead of hills a very gradual sandy slope. This area of gentle slope forms a strip of country bordering the Ocklocknee on the west side and extending through the county.

Little River flows through the county from north to south somewhat east of the middle line. This river and its larger tributaries have cut their valley to a depth of about 100 feet below the general level. The sides of the valleys are usually steep. The tributaries, however, although supplied by springs do not terminate in the characteristic "steepheads" or spring heads found along the Apalachicola River.

GEOLOGY.

The formations found in Gadsden County consist of sands and sandstones, clays, including fullers earth, limestones and marls, all of which are of sedimentary or sedimentary-organic, or of residual origin. The following summary will serve to indicate the relation of the fullers earth series to the overlying and to the underlying deposits.

A surface accumulation of sand occurs extensively in Gadsden County. This sand is of a light to pale yellow color, and is of medium coarse texture. Its depth is variable. In general the sand deepens passing toward the southern line of the county. As seen in the cut at Nicholson and elsewhere this sand has a thickness of 0 to 9 feet and rests with a seeming unconformity upon the formation beneath. Sands of this character in the State have usually been regarded as of Pleistocene age and their presence is commonly cited as indicating a complete re-submergence of the peninsula during the Pleistocene period. As seen in Gadsden County, however, it seems not impossible that these sands are of residual origin.

Beneath these superficial sands, or at the surface when the sands are absent, is found a series consisting of red sands and sandy clays. The subdivision and classification of this series is rendered difficult by the absence of fossils and by the variable character of the strata. Along the Apalachicola River and for some distance inland from that river the top member of this series is a very coarse cross-bedded sand or sand-pebble-conglomerate, varying in color from rich red to light red or gray. This material is often sufficiently indurated to form steep cliffs near the border of the plateau and near the heads of streams where erosion is rapid. This material in the Chattahoochee Landing section has a thickness of 28 feet. The sands as seen in this section are of a rich red color. It is faintly stratified and cross bedded. Siliceous pebbles, most of which are stained brown with iron, are abundant especially toward the base. The sand also is coarser near the base. A stratum of iron concretions occurs 13 feet from the base. This formation here rests upon pinkish sandy clay. Along the river road south from River Junction frequent exposures of this formation occur. In one of these exposures about three and one-half miles south of River Junction as much as 22 feet of the coarse sand pebble conglomerate is seen, while iron concretions remain in profusion, the residuum of that part of the formation which has been removed by erosion. In these exposures the formation upon decay becomes mottled and blotched to a depth of one to five feet, attended often with the formation of indurated crusts.

About two miles northeast of Aspalaga Bluff (Sec. 29, T. 3 N., R. 6 W.) an exposure occurs showing 20 feet of this formation. At the top, this section is discolored and blotched by decay and is overlaid by about 3 feet of ochre yellow sand with iron concretions which has resulted apparently from the decay of this stratum. The formation here rests unconformably upon yellow-red sandy clays with white partings. Eight feet of this latter formation are exposed.

In the section in Liberty County about one mile east of Rock Bluff Landing as much as 36 feet of this material is seen in place. Exposures are also seen at the heads of streams one to one-half miles south of Bristol. Along the Chipola River, at Darling's slide, 14 feet of similar material is seen lying beneath 11 feet of pale yellow sand, and above the sandy micaceous clay and fossiliferous Miocene marls. The matrix holding the plastic kaolin or ball clay in the peninsular section of the State is as previously stated (p. 242) of similar material and apparently represents an eastward and southward extent of this formation in a slightly modified form, being here locally free from iron staining.

Passing to the east in Gadsden County from the Apalachicola River one scarcely finds materials of this formation so coarse in texture as that seen along the river. White water worn pebbles, however, are present and coarse lenses occur occasionally. The Seaboard Air Line railroad in passing on to the plateau at the head of Mosquito Creek cuts through reddish sands near the top of the section, which from their position are probably the eastward extent of the same formation. In this exposure, however, and usually throughout central and eastern Gadsden County, as well as in Leon County the sands of this formation are less coarse in texture than near the river. In the section at Nicholson (p. 284) this formation is represented by 10 to 12 feet of non-stratified faintly cross bedded medium coarse sands which lie unconformably upon finely laminated sandy clays. Although usually a sand varying in texture from medium coarse to very coarse, this formation contains also clay lenses of limited extent.

The intense cross bedding found in these deposits together with their variable character, indicates deposition in shallow water in presence of conflicting currents. Unconformities in this part of the section are numerous, but apparently of local extent. The stratification or bedding, except where affected by cross bedding or local clay lenses is horizontal. The succession beneath this coarse sand is lacking in uniformity. Very frequently, as in the section two miles northeast of Aspalaga, a reddish sandy clay with white clay partings lies beneath the coarse sand. Material of this character occurs widely distributed not only in Gadsden but in Leon and Jefferson Counties. This in turn is underlaid by finely laminated clays and by greenish alum tasting clay such as that found in the section near Rock Bluff Landing (p. 274). Beneath the greenish clay is found the fullers earth series.

The total thickness of the formations lying above the fullers earth when not reduced by erosion is about 100 feet.

In the Rock Bluff section (p. 273) the fullers earth is underlain by approximately 100 feet of yellow gray and blue more or less calcareous sands which represent the Alum Bluff formation. Beneath these sands is found the Chattahoochee limestone. The Alum Bluff sands and the Chattahoochee limestone will be described in connection with the Apalachicola River section on the following pages. Beneath the Chattahoochee limestone the Vicksburg or Lower Oligocene may be expected. The Vicksburg, however, is not exposed at the surface in Gadsden County.

THE APALACHICOLA RIVER SECTION.

The Apalachicola River section is classic in the study of Florida geology. Since the discovery by Langdon in 1887 of the excellent exposures along the river this section has been repeatedly visited and studied by geologists, and a relatively rich literature has developed. The following papers, listed in the Bibliography of Florida Geology, First Annual Report, pp. 73-108, 1908, relate to the Apalachicola River section.

1889—Langdon, Daniel W., Jr. Some Florida Miocene. Am. Journ. Sci. (3) XXXVIII, 322-324, 1889. Republished with some additions in Geology of the Coastal Plains of Alabama, Geol. Surv. Ala., pp. 373-376, 1894.

1891—Johnson, Lawrence C. The Chattahoochee Embayment. Geol. Soc. Am. Bull III, 128-132 1891.

1891—McGee, W. J. The Lafayette Formation. U. S. Geol. Surv. 12th Ann. Rept. pt. i, pp. 347-521, 1891.

1892—Dall, W. H. and Harris, G. D. Correlation Papers: Neocene of North America. U. S. Geol. Surv. Bull. 84, 1892.

1893—Foerste, Aug. F. Studies on the Chipola Miocene of Bainbridge, Georgia, and of Alum Bluff, Florida. Am. Jour. Sci. (3) XLVI, 244-254, 1893.

1893—Pumpelly, Raphael. An Apparent Time-break between the Eocene and the Chattahoochee Miocene in Southwestern Georgia. Am. Journ. Sci. (3) XLVI, 445-447, 1893.

1894—Dall, W. H. and Stanley-Brown, J. Cenozoic Geology along the Apalachicola River. Geol. Soc. Am. Bull. V, 147-170, pl; abst. Am. Geol. XIII, 137-138 (½ p.), 1894.

1894—Foerste, Aug. F. The Upper Vicksburg Eocene and the Chattahoochee Miocene of Southwest Georgia and adjacent Florida. Am. Journ. Sci. (3) XLVIII, 41-54, 1894.

1898—Dall, W. H. A Table of North American Tertiary Horizons, correlated with one another and with those of Western Europe, with annotations, U. S. Geol. Surv. 18th Ann. Rept., pt. ii, 323-348, 1898.

1902—Maury, Carlotta J. A Comparison of the Oligocene of Western Europe and the Southern United States. Am. Paleon. Bull. 15, 1902.

1902—Harris, G. D. Sections along the Apalachicola River. Contained in paper by Maury cited above, pp. 53-58, 1902.

1902—Vaughan, T. Wayland. Fullers Earth of Southwestern Georgia and Western Florida. U. S. Geol. Surv. Min. Res. for 1901, 922-934, 1902. Republished with some additions. U. S. Geol. Surv. Bull. 213, 392-399, 1903.

1903—Dall, W. H. Contributions to the Tertiary Fauna of Florida. Wag. Free Inst. Sci. Trans. III, pts. I-VI, 1890-1903.

1905—Cowles, H. C. A Remarkable Colony of Northern Plants along the Apalachicola River, Florida, and its Significance. Rept. 8th International Geographic Congress, 1904, 599, 1905.

1906—Smith, Eugene A. On Some Post-Eocene and other Formations of the Gulf Region of the United States. Science (n. s.) XXIII, 481-491, 1906; Am. Assoc. Adv. Sci. Proc. LV, 357-374, 1906.

In connection with the investigation of fullers earth deposits in Florida by the State Geological Survey it became necessary to review the river section and to use these well known exposures as a starting point in tracing the formations into the interior.

The Apalachicola River, formed at the Florida line by the union of the Flint and Chattahoochee Rivers, flows across Florida, entering the Gulf of Mexico at St. Andrews Bay. From the Florida line to Alum Bluff a distance of twenty miles the river valley runs in a direction north of northeast to south of southwest. The valley throughout this part of the river's course presents a characteristic lack of symmetry. The southeast side of the valley is bordered by an abrupt bluff, which, although variable in steepness and in height, is continuous, except where cut across by streams entering from the east. On the west side of the river, on the contrary, while the country is somewhat rolling, the slope to the river is gradual. The river valley has here a width of one to two miles and supports a dense growth of hard wood vegetation. The valley subject to overflow is known as the "river swamp."

The river channel winds through the valley in a manner normal to rivers in this stage of development, having shifted its course from time to time, in this way forming the bluff which now borders the val-

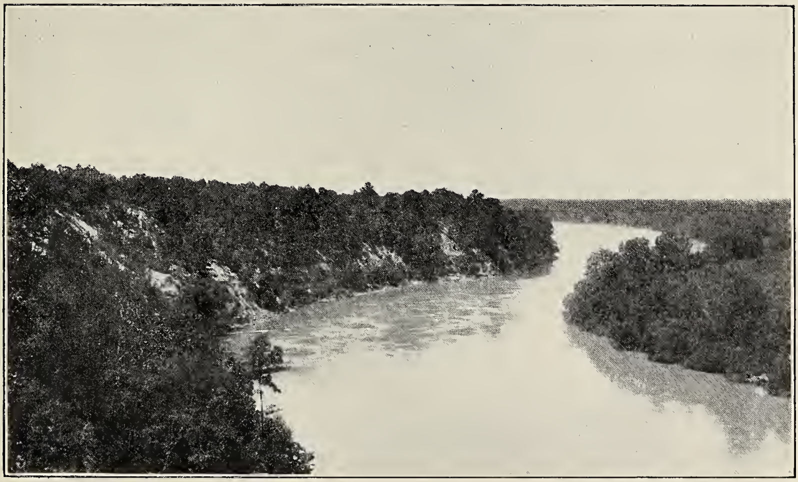


Photo by Harper.

FIG. 1.—APALACHICOLA RIVER, LOOKING SOUTH FROM ALUM BLUFF.

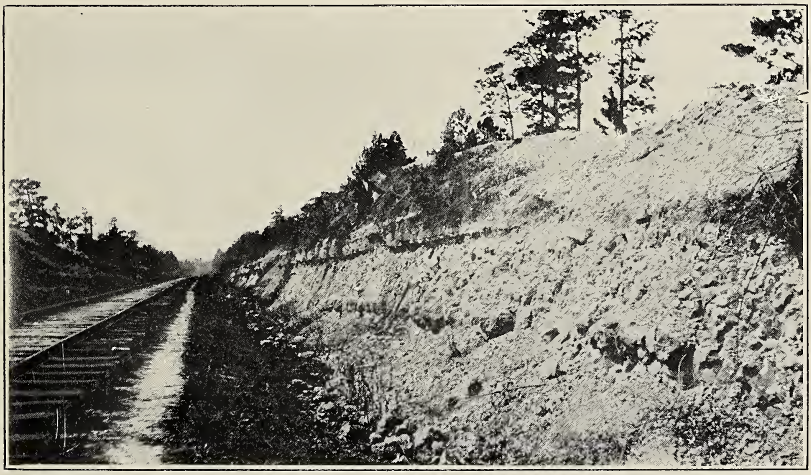


FIG. 2.—EXPOSURE OF CHATTAHOOCHEE LIMESTONE ON A. C. L. R. R. RIVER JUNCTION.

ley. At the present time the river strikes the east bluff at three points known as Aspalaga Bluff, Rock Bluff, and Alum Bluff. An excellent natural section is obtained at each of these three points. At Chattahoochee Landing near the north line of the State the river channel approaches within about one-fifth mile of the bluff. A good section is obtained along the public road leading down to this landing.

The measurements of the following sections have been checked, and are believed to be accurate within the limits necessary for correlation purposes. On March 5, 1909, the gauge on the railroad bridge at River Junction read 7½ feet. As a matter of convenience and to facilitate comparison, the measurements of all sections are given as of this stage of the river.

Section at Chattahoochee Landing.

The section at Chattahoochee Landing is made along the public road leading from Chattahoochee to the river. The exposure begins about one-fifth mile from the river, and is measured along the public road a distance of perhaps somewhat more than one-fourth mile to the top of the plateau. In the lower part of the section while crossing the Chattahoochee limestone the road runs in a direction northwest to southeast. At the top of this first part of the hill the road turns almost at a right angle to the northeast, again turning east as the top of the last hill is reached.

		Thickness of stratum.	Height above river (stage of Mar. 5, 1909).
12.	Rich red sand containing, especially toward the base, an abundance of siliceous pebbles, light colored or stained brown by iron. The sand becomes coarser toward the bottom. Feeble cross bedding and stratification is seen. A layer of iron concretions occurs 13 feet from the base, or 15 feet from the top........	28 feet	154 to 182 feet.
11.	Pinkish and purple sandy clays in horizontal position	9 feet	145 to 154 feet.
10.	Covered and sloping	42 feet	103 to 145 feet.
9.	Marly limestone	4 feet	99 to 103 feet.
8.	Covered and sloping....................	14 feet	85 to 99 feet.
7.	Light colored clayey limestone, with clay inclusions near the top.........	26½ feet	58½ to 85 feet.
6.	Sandy pale yellow limestone...........	4 feet	54½ to 58½ feet.
5.	Lime clay stratum similar in character to that found at Aspalaga Bluff, the top of which in that section lies at the north end of the bluff 19¾ feet above the river at same stage of water	3¾ feet	50¾ to 54½ feet.

	Thickness of stratum.	Height above river (stage of Mar. 5, 1909).
4. Clayey limestone, alternating ledges of harder material with lime clay strata intervening	16½ feet	34¼ to 50¾ feet.
3. Stratum of greenish calcium carbonate crystals imbedded in a soft marly matrix	1 foot	33¼ to 34¼ feet.
2. White soft clayey limestone with ledges of harder, more compact limestone. Some shells as casts and also occasional manatee ribs are found in this part of the section...............	12 feet	21¼ to 33¼ feet.
1. Covered from the river to the base of the section a distance of about one-fifth mile	21¼ feet	0 to 21¼ feet.

The alternating ledges of harder and softer material in the limestones of this section afford an opportunity of measuring the dip. In the direction northwest to southeast the limestone strata in this section show no dip whatever, lying exactly on the level through the distance along which the edges of the individual strata are exposed amounting to 40 or 50 feet. At the top of the hill where the road turns abruptly to the northeast the top of the stratum of the limestone exposure was found to dip to the northeast one foot in thirty feet or at the rate of 176 feet per mile. These observations are in accord with those made at other localities, showing that the strata of the Chattahoochee limestone are mildly folded, presenting numerous small anticlines and synclines.

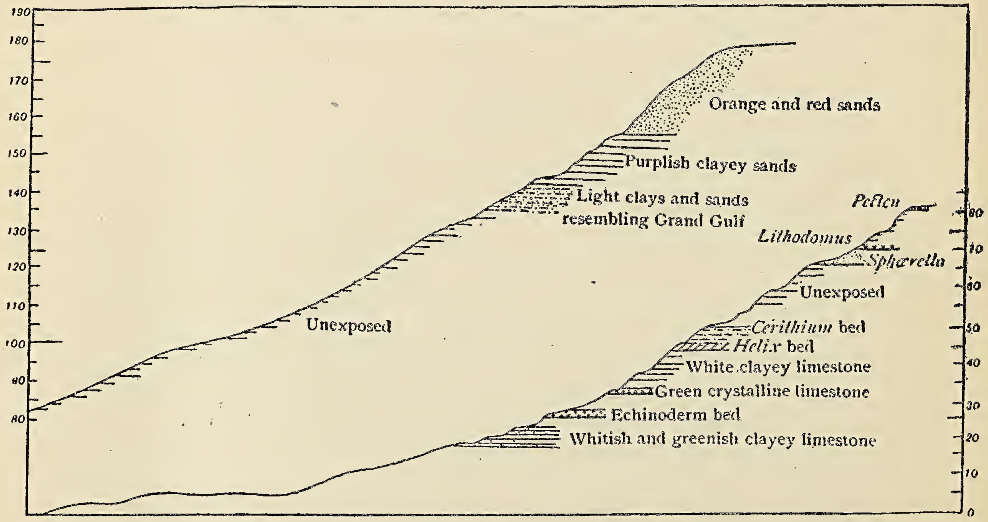


Fig. 4. Section at Chattahoochee Landing. After Harris. From Maury's Oligocene of the Southern United States.

The section at Chattahoochee Landing accordingly represents the north incline of one of these small folds.

A section made at this locality by Harris is contained in Maury's "Oligocene of the Southern United States," and as it was presented in graphic form is republished for comparison. (Text Fig. 4). At the time Harris' section was made the four feet of marly limestone (No. 9 of the writer's section) lying at the level 99 to 103 feet above the river was not exposed. Aside from this point the writer's section agrees in the main with that made by Harris. Sections made by Dall and Vaughan at or near this place have been included in the report on stratigraphy (p. 79). Dall's section may have been made along a road leading from the landing different from the road now in use as the measurements given by him do not correspond to the section now exposed.

An instructive partial section may be seen along the Atlantic Coast Line Railroad one-half to one mile northeast of River Junction station. At a distance of about one-half mile from the station a shallow cut exposes the north slope of a small anticline. The section in this cut is as follows:

	Thickness of stratum.	Height above river (stage of Mar. 5, 1909).
2. Lime clay stratum similar to strata seen in the section at Chattahoochee Landing	7 feet	41¼ to 48¼ feet.
1. Pale yellow sandy limestone	4 feet	37¼ to 41¼ feet.

The direction of the change of level in this exposure is north of northeast, and the dip is at the rate of slightly more than 100 feet per mile.

A small stream cuts across about one-eighth mile beyond this cut and exposes the bottom or near the bottom of this syncline. In this stream a lime-clay stratum apparently the same as the above is seen lying at a level 34 feet above the river stage of March 5, 1909.

Beyond the stream the strata rise, forming a second anticline. A shallow cut somewhat less than one-eighth mile beyond the stream gives the following section.

	Thickness of stratum.	Height above river (stage of Mar. 5, 1909).
2. Light colored sandy limestone	2 feet	41¾ to 43¾ feet.
1. Lime-clay stratum	6½ feet	35¼ to 41¾ feet.

The observed rate of dip in this exposure is approximately 100 feet per mile in a direction south of southwest.

The top of this anticline is reached and passed in a shallow cut about one-seventh of a mile beyond and across a second small branch. This cut gives the following section:

		Thickness of stratum.	Height above river (stage of Mar. 5, 1909).
3.	Lime-clay stratum, basal part remaining at the top of the cut, about.....	1 foot	43¾ to 44¾ feet.
2.	Yellow sandy limestone	4 feet	39¾ to 43¾ feet.
1.	Light colored limestone...............	4 feet	35¾ to 39¾ feet.

The top of the anticline is passed before reaching this section and the strata are again dipping slightly to the north of northwest.

These sections, including the one at Chattahoochee Landing, prove the existence of small folds in the limestone the axis of the folds being in general northwest to southeast.

The following section is found on the Chattahoochee-Quincy road at the crossing of North Mosquito Creek one mile east of Chattahoochee.

		Thickness of stratum.	Height above river (stage of Mar. 5, 1909).
8.	Covered and sloping to the upland plateau, about	132 feet	68 to 200 feet.
7.	Limestones, the lower strata hard and weathering rough, higher strata softer and clayey	15¼ feet	52¾ to 68 feet.
6.	Covered and sloping	1½ feet	51¼ to 52¾ feet.
5.	Pale yellow impure sandy limestone....	4 feet	46¾ to 51¼ feet.
4.	Lime-clay stratum similar in character to the lime-clay strata in section at Chattahoochee Landing	7½ feet	39¼ to 46¾ feet.
3.	Sloping and covered	21¾ feet	17½ to 39¼ feet.
2.	Pale yellow sandy limestone...........	3¼ feet	14¼ to 17½ feet.
1.	The base of this section lies about two miles from the river and above the river level		14¼

At the crossing of the Seaboard Air Line Railroad on Mosquito Creek the following section is seen:

		Thickness of stratum.	Height above river (stage of Mar. 5, 1909).
3.	Pale yellow sandy limestone..........	5¼ feet	12¾ to 18 feet.
2.	Gray sandstone	2¾ feet	10 to 12¾ feet.
1.	Covered from the river a distance of about one and one-half miles. Base of section above the river, about....		10 feet.

The gray sandstone at the base of this exposure is topographically the lowest member of the Chattahoochee series seen in Florida. It lies at this bridge at about ten feet above the river stage of March 5, 1909; while in the section at Chattahoochee Landing the base of the section is 21½ feet above the river at the same stage.

Section at Aspalaga Bluff.

Aspalaga Bluff is seven miles in a direct line from the north boundary of the State and is the first point in Florida at which the river channel strikes the east bluff. The following section was made near the north end of that part of the bluff facing the river. A continuous exposure is not found in any direct line of sectioning. In order to determine thickness of strata it is often necessary to transfer the level for short distances along the side of the bluff.

		Thickness of stratum.	Height above river (stage of Mar. 5, 1909).
12.	Covered in the line of sectioning to the top of the bluff about one-fourth mile back from the river, about..........	60 feet	114 to 175 feet.
11.	Sloping and covered except for occasional outcrops of impure limestones mostly containing fossils as casts...	51 feet	63 to 114 feet.
10.	White granular limestone with numerous shells as casts...............	2 feet	61 to 63 feet.
9.	White limestone becoming upon exposure hard and of a pinkish color (exposed)	4 feet	57 to 61 feet.
8.	Steep slope partly covered but with frequent and almost continuous exposures of light colored impure limestone often with clay inclusions	23 feet	34 to 57 feet.
7.	White granular limestone with numerous fossils as casts.............	1 foot	33 to 34 feet.
6.	White limestone becoming upon exposure hard and of a pinkish color.	2½ feet	30½ to 33 feet.
5.	Light colored limestone weathering rough	2 feet	28½ to 30½ feet.
4.	White limestone becoming upon exposure hard and of a pinkish color..	6 feet	22½ to 28½ feet.
3.	Sandy light to pale yellow limestone....	2¾ feet	19¾ to 22½ feet.
2.	Gray to bluish calcareous clay which upon drying breaks with a tendency to conchoidal exfoliation	4 feet	15¾ to 19¾ feet.
1.	Limestone at the base to water's edge yellowish and sandy with few fossils, above lighter colored with small fossils as casts, near the top clayey.	15¾ feet	0 to 15¾ feet.

The calcareous clay (No. 2) of the Aspalaga section forms a very characteristic stratum. This stratum seen in numerous exposures from Chattahoochee to Aspalaga is very porous and of light specific gravity, and except for the presence of calcium carbonate has many resemblances to fullers earth. The following is an analysis of a sample from

Aspalaga. Analysis made for the State Survey in the office of the State Chemist, B. H. Bridges, Analyst.

Silica (SiO_2)	39.08
Calcium oxide (CaO) 12.00, $CaCO_3$ (calculated)	21.80
Magnesium oxide (MgO) 8.86, $MgCO_3$ (calculated)	18.48
Iron and alumina (Fe_2O_3), Al_2O_3	11.60
Phosphoric acid	00.00
Sulphate (SO_4)	Trace
Moisture (100 degrees F.)	1.50

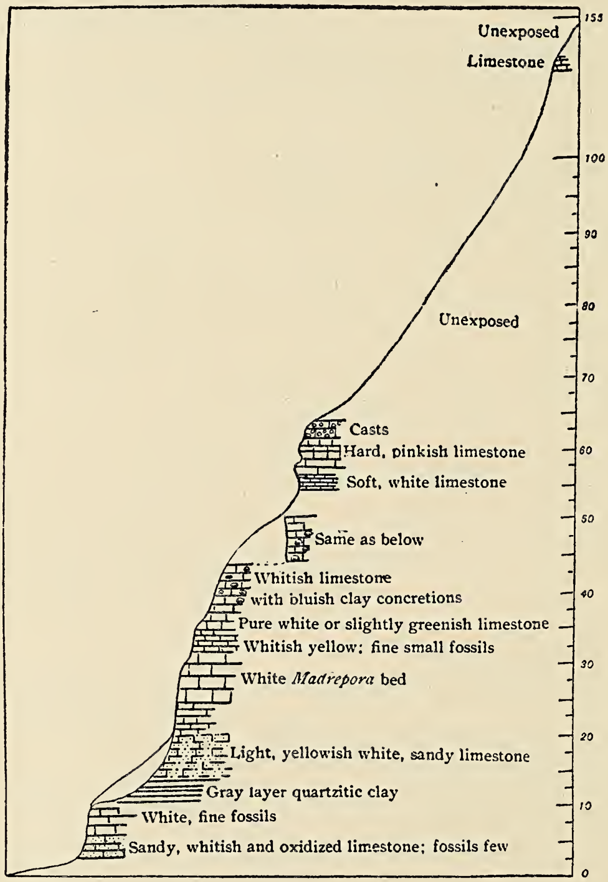

155
Unexposed
Limestone
100
90
80
Unexposed
70
Casts
Hard, pinkish limestone
60
Soft, white limestone
50
Same as below
Whitish limestone
with bluish clay concretions
40
Pure white or slightly greenish limestone
Whitish yellow: fine small fossils
30
White *Madrepora* bed
20
Light, yellowish white, sandy limestone
Gray layer quartzitic clay
10
White, fine fossils
Sandy, whitish and oxidized limestone; fossils few
0

Fig. 5. Section at Aspalaga Bluff. After Harris. From Maury's Oligocene of the Southern United States.

The following is an analysis of a sample taken from a similar stratum, one mile east of Chattahoochee (No. 4 of section given on page 270). Analysis for the State Survey made in Office of the State Chemist, B. H. Bridges, Analyst.

Silica (SiO_2)	63.32
Calcium oxide (CaO) 1.47, $CaCO_3$ (calculated)	2.63
Magnesium oxide (MgO) 5.20, $MgCO_3$ (calculated)	10.90
Iron and alumina (Al_2O_3), Fe_2O_3	11.64
Phosphoric acid	None
Sulphate (SO_4)	Trace
Moisture (100 degrees F.)	6.22

The upper part of the bluff in the line of sectioning at Aspalaga amounting to about sixty feet was covered at the time the section was made. Professor G. D. Harris who made a section of this bluff in 1901 found limestone containing *Pecten* and *Placuna* in place at an elevation of 145 feet above the base of the bluff. According to Harris' observation the lower one-half or more of this covered interval is occupied by deposits with at least occasional limestones or marls. Near the top of the section one should expect to find the coarse red sand common to this region, and in fact an exposure of ten or twelve feet of this material occurs near the public road, possibly one-half mile from the face of the bluff. Two miles northeast of Aspalaga in Section 29, T. 3 N., R. 6 W., an exposure occurs showing at the top of the plateau twenty feet of coarse red sand resting unconformably on sandy reddish clays with white clay partings.

Section at Rock Bluff.

Rock Bluff lies five and one-half miles in a direct line south of southwest of Aspalaga Bluff, or twelve and one-half miles from the State line. It is the second point at which the river in Florida strikes the east border of the river valley. That part of Rock Bluff which faces the river lies near the southwest corner of Section 17, R. 7 west, T. 2 north. The basal part of the following section is made near the north end where the river channel first strikes the bluff. From this point the level was transferred north across a small stream to that part of the bluff which does not now directly face the river.

		Thickness of stratum.	Height above river (stage of Mar. 5, 1909).
11.	Covered in the line of the section to the top of the bluff from the river, about ¼ mile	100 feet	100 to 200 feet.
10.	Fullers earth (exposed)	3 feet	97 to 100 feet.
9.	Ledge with shells	1 foot	96 to 97 feet.
8.	Gray sand	5 feet	91 to 96 feet.
7.	Ledge with shells	2 feet	89 to 91 feet.
6.	Gray sand with lime inclusions	5 feet	84 to 89 feet.
5.	Covered	2 feet	82 to 84 feet.
4.	Light gray calcareous sand containing a trace of phosphate (by transferring the level across a small branch to the north the section is continued)	30 feet	52 to 82 feet.

3.	Bluish green to gray sands, variable in character. Lime inclusions begin to appear in these sands at 20 feet from the base. These become more numerous until the material passes gradually into the sandy-marl above.	34 feet	18 to 52 feet.
2.	Compact sandy marl with concretions near the base and with an ostrea layer 6 feet above the base..........	8 feet	10 to 18 feet.
1.	Chattahoochee limestone above water level	10 feet	0 to 10 feet.

By following a small stream entering at the south end of Rock Bluff the following supplementary section was obtained.

Section About One Mile Southeast of Rock Bluff.

		Thickness of stratum.	Height above river
14.	Superficial sand at the surface.		
13.	Reddish, coarse sand, "Altamaha Grit" phase. The surface of the ground near the brink of the cliff is profusely covered with iron concretions, remaining as residual material from the decay of the formation. The first 1 to 4 feet of the sand is discolored and mottled and shows a tendency to the formation of iron stained crusts. Iron concretions occur in the sand from the surface to a depth of seven feet. These show a tendency towards arrangement in layers. One such layer is observed to extend from the mottled and decayed surface material downwards and horizontally into material apparently not appreciably affected by decay. The sand is usually cross bedded, containing white siliceous pebbles	36 feet	164 to 200 feet.
12.	Partly covered by land slides and with some seepage water emerging near the base	15 feet	149 to 164 feet.
11.	Sandy yellowish laminated clays giving rise to small springs	2 feet	147 to 149 feet.
10.	Pink clays, free from sand and very plastic	2 feet	145 to 147 feet.
9.	Yellow sandy clays	3 feet	142 to 145 feet.
8.	White water worn elongated siliceous pebbles imbedded in yellow sandy clays and lying with long axis parallel with the lines of stratification...	1 foot	141 to 142 feet

7.	Yellow plastic clays containing some sand	7 feet	134 to 141 feet.
6.	Greenish sticky clay with aluminous taste. This clay contains a small amount of sand. Upon drying it contracts, forming cubical blocks and ultimately falls into small pieces (exposed)	9 feet	125 to 134 feet.
5.	Covered and sloping	45 feet	80 to 125 feet.
4.	Sand, blue in fresh exposure, yellow upon decay	6 feet	74 to 80 feet.
3.	Covered	2 feet	72 to 74 feet.
2.	Calcareous sands (exposed)	12 feet	60 to 72 feet.
1.	Covered to the water level (about)	60 feet	0 to 60 feet.

The covered interval as given here is based upon barometer readings several times checked. These readings give the top of this section as about 200 feet above the river.

Section at Alum Bluff, Liberty County.

The following section was made at Alum Bluff a short distance north of the middle of the bluff at a point where a recent landslide (reported to have occurred in 1905 or 1906) has left the bluff bare of vegetation (see pl. 1). The measurements of this section were made by hand level.

		Thickness of stratum.	Height above river (stage of Mar. 5, 1909).
8.	Pale yellow incoherent sand	30 feet	136 to 166 feet.
7.	Reddish and purple sands and sandy clays partly covered toward the base	70 feet	66 to 136 feet.
6.	Covered	6 feet	60 to 66 feet.
5.	Dark colored sandy non-fossiliferous clays, in places tasting of alum	17 feet	43 to 60 feet.
4.	Dark or gray marls, highly fossiliferous	14 feet	29 to 43 feet.
	Unconformity.		
3.	Laminated and cross bedded sands and clays, and blue sands; in places absent	3 feet	26 to 29 feet.
	Apparent unconformity.		
2.	Light gray calcareous sands or sandstone	16 feet	10 to 26 feet.
1.	Sands, slightly indurated and weathering yellow upon exposure	10 feet	0 to 10 feet.

The light gray sandstone (No. 2) of this section is apparently the same as No. 4 of the Rock Bluff section (p. 273), the stratum having been recognized at several intermediate localities along the river bluff between the two localities and on tributaries entering the river. Samples from this stratum gave the following analyses. No. 1 is from

Rock Bluff (No. 4 of the section). No. 2 is from Alum Bluff (No. 2 of the section). No. 3 from an exposure on a tributary to Sweet Water Creek Sec. 5, T. 1 N., R. 7 W. All samples were collected by the writers.

Analyses made for the State Survey in the office of the State Chemist, B. H. Bridges, Analyst.

	No. 1.	No. 2.	No. 3.
Silica (SiO_2)	48.44	53.02	34.03
Calcium carbonate ($CaCO_3$)[1]	38.57	38.57	35.35
Magnesium carbonate ($MgCO_3$)[1]	1.68	1.84	26.00
Iron and Alumina (Fe_2O_3 and Al_2O_3)	2.88	3.96	3.20
Phosphoric acid (P_2O_5)	Trace	0.22	Trace
Sulphate (SO_4)	Trace	Trace	Trace
Moisture (100 degrees F.)	1.37	1.60	1.32

Above this stratum at Rock Bluff is found gray and blue sands leading up to the workable fullers earth stratum. At Alum Bluff the fullers earth fails to appear, and the top surface of the calcareous sand stratum is irregular as if by erosion. In some parts of the bluff fossiliferous Miocene marl rests directly upon these sands. Usually, however, the calcareous sands are separated from the Miocene by laminated or cross bedded sands and clays often carrying vegetable remains. At Rock Bluff the calcareous sands have a total thickness of 30 feet. At Alum Bluff, owing to the irregular top surface, the thickness is variable. At one point near the middle of the bluff this stratum is lacking although elsewhere it has a thickness of 9 to 16 feet.

The cross bedded sands and laminated sands and clays lying above the calcareous sands are extremely variable in thickness, being not infrequently absent. They seem in fact merely to occupy irregularities in the top surface of the calcareous sands. An exposure about 300 feet from the north end of the bluff gives the following section:

Covered to the top of the hill.	
Dark colored alum tasting clays	10 feet.
Fossiliferous Miocene marl	10 feet.
Unconformity.	
Laminated clays and sands with plant remains, and blue sands	7 feet.
Irregularity or unconformity.	
Calcareous sands	13 feet.
Sloping from the water's edge	15 feet.

A small stream enters just below this section. At this point is seen sands with buff colored clay partings, and plant remains, grading at the base into blue sands, having a total thickness of 8 feet. The greatest thickness observed, 21½ feet, is at a point near the middle of the bluff, at which place Dall's section (p. 93) was made. The cross bedded sands here rest directly upon the fossiliferous Chipola beds, the calcareous sand stratum being as previously stated absent at this point.

---

[1] Calculated from the oxides. No. 1, Calcium oxide, 21.60; magnesium oxide, 0.80. No. 2, Calcium oxide, 21.60; magnesium oxide, 0.88. No. 3, Calcium oxide, 19.80; magnesium oxide, 12.39.

FOLDS IN THE CHATTAHOOCHEE LIMESTONE.

The sections of the Chattahoochee limestone at Chattahoochee Landing, in the vicinity of Chattahoochee and of River Junction, give evidence as previously stated (p. 270) of small anticlines and synclines. Aspalaga Bluff affords an opportunity of tracing the several strata through a distance of about one-half mile. The direction of the exposure here is from north of east to south of west. The section given above is made at the north end of the bluff. The lime-clay stratum (No. 2) of that section is very characteristic lithologically and is easily traced, forming in fact a bench along which one may walk the entire length of the bluff. The top of this stratum at the north end of the bluff lies, as indicated in the section, 19¾ feet above the river. At the middle of the bluff about ¼ mile down stream the top lies 12½ feet above the water level. Near the landing the top of the stratum is again 16¾ feet above the water at the same stage. Beyond the landing the top of this stratum as seen along the small stream lies about 13 feet above the river. Stratum No. 10, containing numerous fossils as casts, the base of which at the north end of the bluff lies 61 feet above the river, is found in the section at the middle of the bluff, 55 feet above the river. The intervening strata are recognizable and occupy their respective positions. It is thus seen that a small syncline lies near the middle of Aspalaga Bluff. The top of the corresponding small anticline is probably reached, at or near the landing, as indicated by the level of the clay stratum in the branch beyond or within a distance of about ¼ mile from the bottom of the syncline. The rate of dip of the strata is less in this section than in some of the sections near Chattahoochee.

Unmistakable evidence of dislocation of strata is seen at Rock Bluff, where a sharp break occurs in the Chattahoochee limestone near the middle of the bluff and slightly above low water level.

DIP OF THE CHATTAHOOCHEE LIMESTONE.

The rate of dip of the Chattahoochee limestone has been estimated by several geologists who have visited the locality. Johnson (l. c. p. 128) observed in these formations a "general dip toward the south." This writer notes also a "westerly dip," as a consequence of which "there is a thinning out of the strata eastward and northward and a deepening of accumulation toward the west and south." Langdon (l. c. p. 323) had previously estimated the rate of dip of the formations overlying the Chattahoochee limestone at about twenty-six feet per mile. Langdon does not state, however, specifically that a similar rate of dip applies to the limestone, although such inference is perhaps implied. Foerste assumed (l. c. p. 54) for the Chattahoochee a slope of about nine feet per mile. Harris (l. c. p. 58) estimates the dip in the strata from the north end of Aspalaga Bluff to Rock Bluff, at an average of twenty-three feet per mile.

In determining the rate of dip the effect of the folds in the strata must be taken into consideration. This is especially true of estimates made through short distances. The rocks at the Chattahoochee Landing section were found to dip northeast at a rate roughly estimated at 176 feet per mile. The dip of the strata through short distances in the direction north of northeast in the cuts along the Atlantic Coast Line Railroad northeast of River Junction was found to be approximately 100 feet per mile. Along the face of Aspalaga Bluff the change of level in the strata can be measured in the direction south of west to north of east. In this section a change of level of at least as much as thirty feet per mile may be observed. In all these sections the rapid dip is accounted for as previously explained by the presence of numerous small anticlines and synclines. To determine even approximately the average dip it is necessary that the level of a single stratum should be determined through a considerable distance. Stratum No. 2 of the Aspalaga section is very characteristic lithologically and cannot be confused with any other stratum of that section, certainly not with any stratum lying above it. Followed toward the north this stratum is seen occasionally along the side of the bluff at successively greater elevations above the river. Three miles southwest of River Junction the top of this stratum lies, according to an approximate measurement, about thirty-five to forty feet above the river level (stage of March 5, 1909.) At Chattahoochee Landing calcareous clays similar in character occur as high as eighty-five feet above the river. Chattahoochee Bluff and Aspalaga Bluff are distant in a direct line seven miles. Since in the Aspalaga section the calcareous clays lie fifteen to nineteen feet above the river and calcareous clays of this character are found at no higher level in this section, the dip of this stratum in the direction south of southwest is believed to be at least fifty feet and possibly more in a distance of seven miles,[1] or seven feet or more per mile. At Aspalaga fully sixty feet of the Chattahoochee limestone stands above the river, while at Rock Bluff, five and one-half miles south of southwest, not more than seven or eight feet stands above water at the same stage of the river. This indicates a dip of at least ten feet per mile. Alum Bluff lies six and one-half to seven miles in a direct line from Rock Bluff. Upon the estimate of a dip of twenty-three feet per mile made by Harris the entire Rock Bluff section of 100 feet, would pass under the river before reaching Alum Bluff. Upon the estimated dip of seven to ten feet per mile the greater part of the Rock Bluff section would pass under the river before reaching Alum Bluff. The latter is probably approximately the rate of dip, as the slightly phosphatic sandstone with lime cement lying near the water in the Alum Bluff section seems to represent the similar rock found in Rock Bluff, forty-six to seventy-six feet above the river. Langdon (l. c. p. 324) expressed the view that the bluffs along the Apalachicola River represented "the western terminations of ridges that extend eastward parallel to each other like gigantic ribs." Dall also assumed that the river at these sections cuts into anticlinal ridges.[1] The writers having followed the river bluff from the Florida line to Alum Bluff find no evidence of large anticlinal ridges of this character. On the contrary, as previously stated, the limestone dips to the south or southwest gradually through a succession of small folds.

---

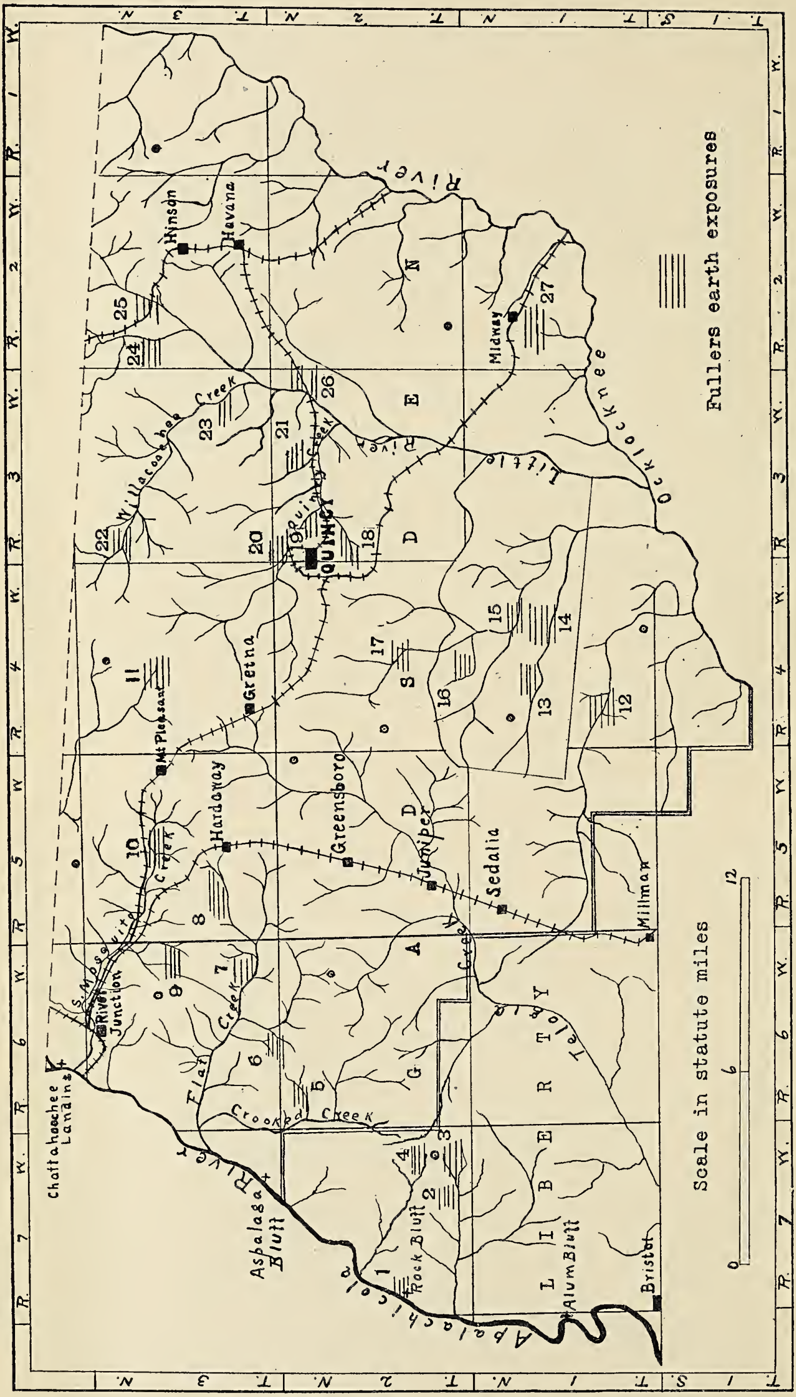
[1] The fall of the river which amounts to between one-half and one foot per mile if allowed for will slightly increase the estimated rate of dip in this and the following measurements.

THE OCKLOCKNEE RIVER SECTION.

The Ocklocknee River lies between Gadsden and Leon Counties, forming the eastern and southeastern boundaries of Gadsden County. From the Florida line to the crossing of the Seaboard Air Line Railroad, a distance of sixteen miles, this river flows north-northeast to south-southwest. Beyond this crossing the river flows to the southwest to the entrance of Telogia Creek, from which point it flows southeast to the Gulf. Ocklocknee thus closely parallels the course of the Apalachicola. The approach to the Ocklocknee River from the west in Gadsden County is by a gradual slope and with one exception no bluffs occur on the west side of the river. In this respect also a parallel between the two rivers is found, the gradual slope to the Apalachicola from the west having been previously mentioned. On the east side of the Ocklocknee, in Leon County, bluffs occur which, although much lower in altitude, may be compared to the bluffs found on the east side of the Apalachicola. A small bluff in Sec. 26, T. 1 N, R. 3. W., on the east bank of the river gave the following approximate section:

---

[1] Cenozoic Geology Along the Apalachicola River, William H. Dall and Joseph Stanley-Brown. Bull. Geol. Soc. Am., vol. v. 1894.



MAP OF FULLERS EARTH EXPOSURES IN GADSDEN AND LIBERTY COUNTIES.

4.	Covered to the top of the bluff, about	20 feet.
3.	Sands weathering yellow	1½ feet.
2.	Greenish and blue sands	1 foot.
1.	Gray calcareous sands	7½ feet.

Fullers earth occurs at a nearby locality and at an elevation of twenty to twenty-five feet above the river. A section of Jackson's Bluff on the Ocklocknee River has been given (p. 114).

FULLERS EARTH OUTCROPS IN GADSDEN COUNTY.

Fullers earth has been observed to occur at the following localities in Gadsden and Liberty Counties as indicated on the accompanying map (pl. xviii). It may be expected to occur at many intermediate localities along the several streams:

1. Rock Bluff (S. 17, R. 7 W., T. 2 N.)
2. Stream tributary to Sweetwater Creek. S. 27, T. 2 N., R. 7 W.)
3. Spring Creek tributary to Sweetwater Creek. (S. 26, T. 2 N., R. 7 W.)
4. Headwaters of Rock Creek. (S. 23, T. 2 N., R.7 W.)
5. Stream tributary to Crooked Creek. (S. 6, T. 2 N., R. 6 W.)
6. Stream tributary to Flat Creek. (S. 33, T. 3 N., R. 6 W.)
7. Flat Creek. (S. 26, T. 3 N., R. 6 W.)
8. Flat Creek. (S. 29, T. 3 N., R. 5 W.)
9. Stream tributary to South Mosquito Creek. (S. 13, T. 3 N., R. 6 W.)
10. South Mosquito Creek. (S. 9, T. 3 N., R. 5 W.)
11. North Mosquito Creek. (T. W. Vaughan.) (S. 16, T. 3 N., R. 4 W.)
12. Ocklawaha Creek. (S. 28, R. 4 W., T. 1 N.)

13 and 14. Bear Creek. (Lots 58 and 49.)

15. Rocky Comfort Creek. (Lot 42.)
16. Stream tributary to Rocky Comfort Creek. (Lot 56.)
17. Rocky Comfort Creek. (S. 21, T. 2 N., R. 4 W.)
18. Stream tributary to Quincy Creek. (S. 18, T. 2 N., R. 3 W.)
19. Quincy Creek. (S. 6, T. 2 N., R. 3 W.)
20. Quincy Creek. (S. 1, T. 2 N., R. 4 W.)
21. Stream tributary to Quincy Creek. (S. 4, T. 2 N., R. 3 W.)
22. Willacoochee Creek. (S. 17, T. 3 N., R. 3 W.)
23. Willacoochee Creek. (S. 26, T. 3 N., R. 3 W.)
24. Attapulgus Creek. (S. 17, R. 2 W., T. 2 N.)
25. Swamp Creek. (S. 17, R. 2 W., T. 3 N.)
26. Little River. (S. 12, R. 3 W., T. 2 N.)
27. Stream tributary to Ocklocknee River. (S. 8, R. 2 W., T. 1 N.)

The fullers earth strata extend, except where removed by erosion, entirely across Gadsden County. The strata lie sensibly horizontal, except where displaced by local slight disturbances.

The accompanying sketch map shows by shading outcrops of fullers earth in this county. Along Little River, and its tributaries, Quincy, Willacoochee, Attapulgus and Swamp Creeks outcrops are very frequent from the Georgia line across the county, exposures occurring, in fact, wherever excavations for public roads or for railroads, or where rapid surface wash has removed the soil and residual material. The dip of the fullers earth stratum from the north to the south line of the county along this river is but slight and apparently scarcely equals the fall of the stream beds. At the Georgia line on Willacoochee Creek the fullers earth stratum lies above the stream bed about fifteen feet. Outcrops seen on Swamp and Attapulgus Creeks within one to two miles of the Georgia line lie at about the same level above the stream beds. In the section at Nicholson on Little River, formed by the union of these two streams and about seven miles south of the state line, the lowest fullers earth seen lies twenty feet above the bed of the stream. At Midway, near the southern part of the county, the fullers earth lies along small streams (Sec. 8, T. 1 N., R. 2 W.) reaching back as much as two miles from Ocklocknee River. At Jackson's Bluff the southernmost exposure of fullers earth seen, the stratum lies above the bed of the Ocklocknee about twenty-five feet. Beyond this point the dip of the strata is doubtless more rapid than the fall of the stream as the bluffs die out toward the coast.

In the western part of this county the fullers earth stratum is cut into by the head waters of both the North and South branches of Mosquito Creek; and farther south by the tributaries to Flat Creek and Crooked Creek, also in Liberty County by the head waters of Rock Creek and Sweetwater Creek. While the tributaries of Little River, flowing in a general north and south direction, flow parallel with the fullers earth strata, the tributaries of the Apalachicola with much steeper gradient, cut across the edge of the fullers earth strata and into the sands, marls and limestones lying below. Although in general horizontal minor folds have been observed in the fullers earth at several localities.

The exposures along Little River give only partial sections of the fullers earth series. Several of these sections follow, which will help to indicate the character of the exposures. With the exception of the sections at Nicholson and at Quincy, the measurements in these partial sections are approximate.

Section in Owl Commercial Company Pit at Quincy.

6.	Sandy, more or less decayed mottled clays of varying thickness and separated by unconformity from the stratum beneath, about...	12 feet.
5.	Bluish colored sand rock with some clay and with occasional shell and marl inclusions	4 feet.
4.	Fullers earth	6 feet.
3.	Sandstone more firmly indurated than above and containing shells	5 feet.
2.	Fullers earth, about	6 feet.
1.	Test pits indicate that the fullers earth is underlaid by sands.	

Section on Public Road about one mile east of Quincy.

5.	Covered to the top of the hill.	
4.	Greenish sticky clay	5 feet.
3.	Fullers earth, about	4 feet.
2.	Calcareous sand rock with fossils	4 feet.
1.	Fullers earth (exposed)	3 feet.

A similar exposure of fullers earth is seen in an open field across the stream to the south.

The following approximate section is seen on the Quincy-Attapulgus road five miles northeast of Quincy. The exposure occurs on the north side of Willacoochee Creek.

5.	Covered to the top of the hill.	
4.	Blue sands which upon exposure oxidize yellow	6 feet.
3.	Fullers earth, about	6 feet.
2.	Sandstone, about	4 feet.
1.	Fullers earth (exposed)	1 foot.

The fullers earth is seen also on the south side of the stream.

Section one mile west of Gatzlaff, on west side of Attapulgus Creek.

5.	Covered to the top of the hill.	
4.	Fullers earth, about	5 feet.
3.	Sandstone	2½ feet.
2.	Fullers earth, about	8 feet.
1.	Sandstone, about	8 feet.

Base of section above stream bed about 10 to 15 feet.

The following approximate section was made at the public road crossing on Bear Creek, nine miles southwest of Quincy and about three-fourths mile east of Gregory postoffice.

6.	Superficial sand, seemingly unconformable upon the underlying formations, and of variable thickness.	
5.	Mottled and more or less decayed sandy clay.	
4.	Mottled sandy clay with many siliceous pebbles especially at the bottom	15 feet.
3.	Sandstone	3 feet.
2.	Fullers earth, about	3 feet.
1.	Sandstone	5 feet.

A small branch entering Crooked Creek from the southeast forms a good section in cutting through the fullers earth series. The following partial section was made at the site of the old dam on this stream:

4.	Base of fullers earth above which in a direct line is covered to the top of the hill.	
3.	Sandstone, decayed and oxidized yellow, about	8 feet.
2.	Fullers earth, good grade at the top. Some sand interbedded near the base	7 feet.
1.	Gray sandstone, vertical and forming waterfall	10 feet.

Farther up stream No. 3 is seen in the bottom and sides of the stream and in the undecayed condition is found to resemble No. 1. The top of this stratum forms a second small waterfall. The fullers earth of No. 4 is seen in place here also. The contact line between the fullers earth and the sandstone is very distinct. At this exposure a mild fold is observed, the fullers earth dipping here at the rate of 142 feet per mile. The dip, however, is local.

The following section was obtained in the railroad cut at Nicholson five miles west of Havana:

Section in Railroad Cut at Nicholson.

		Thickness of stratum.	Above the bed of Little River.
10.	Medium coarse pale yellow superficial sand	10 feet	66 to 76 feet.
9.	Seeming unconformity		66 feet.
8.	Light reddish medium coarse partly indurated, non-stratified, faintly cross bedded sands	9 to 12 feet	54 to 66 feet.
7.	Unconformity		54 feet.
6.	Nicely laminated clays	4 feet	50 to 54 feet.
5.	More massive, buff clays	4 feet	46 to 50 feet.
4.	Laminated clays	8 feet	38 to 46 feet.
3.	Covered along the railroad toward Little River about ¼ mile	13 feet	25 to 38 feet.
2.	Sandy clays overlaid by buff fullers earth	5 feet	20 to 25 feet.
1.	Covered to the bed of Little River, about	20 feet	20 feet.

The following more complete section was obtained along the public road from Nicholson to Little River:

		Thickness of stratum.	Above the bed of Little River.
10.	Superficial sands, same as No. 10 of above section	10 feet	94 to 104 feet.
9.	Red sands	36 feet	58 to 94 feet.
8.	Covered	5 feet	53 to 58 feet.
7.	Nicely laminated clays	11½ feet	41½ to 53 feet.
6.	Buff colored clay	4 feet	37½ to 41½ feet.
5.	Partly covered with occasional sands and sandy clay exposures	4½ feet	33 to 37½ feet.
4.	Sands including some carbonaceous material and resembling No. 2 of above	8 feet	25 to 33 feet.
3.	Blue fullers earth	5 feet	20 to 25 feet.
2.	Gray sandstone	10 feet	10 to 20 feet.
1.	Covered to the bed of the river, about		10 feet.

Practically all of Gadsden County is underlaid by fullers earth, the exposed edges of the strata forming a strip bordering most of the streams.

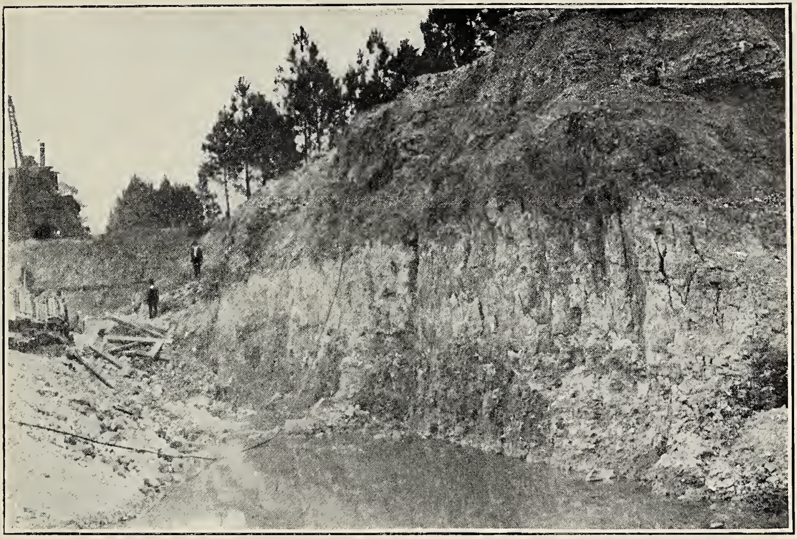


FIG. 1.—VIEW IN PIT OF OWL COMMERCIAL CO., QUINCY.

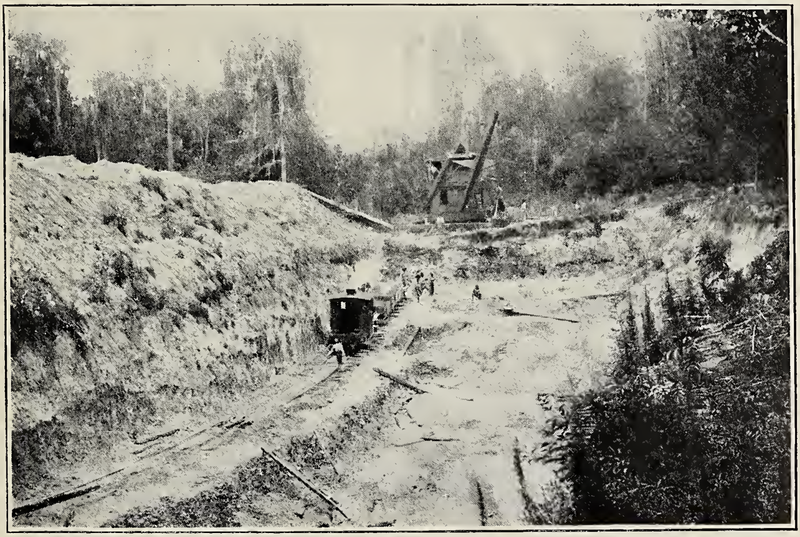


FIG. 2.—VIEW IN PIT OF OWL COMMERCIAL CO., QUINCY.

AMOUNT OF FULLERS EARTH IN GADSDEN COUNTY.

The total amount of workable fullers earth in Gadsden County is difficult to estimate. Fullers earth of the average thickness of the stratum as found in this section may be assumed to yield as a minimum 5,000 tons per acre. While the fullers earth actually underlies the greater part of the county the workable area under present conditions is restricted to the lands lying near the streams or elsewhere where the overburden does not exceed ten to fifteen feet in thickness. It is possibly safe to estimate that 3,456 acres of land, or approximately one per cent of the total area of Gadsden County is underlaid by workable fullers earth. This area with an average yield of 5,000 tons per acre will supply 17,280,000 tons or enough fullers earth to supply the demand at the present rate of consumption of this grade for about 500 years. It is true that much of the fullers earth included in the above estimate occurs in sections which are at present remote from railroads or other means of cheap transportation. It is safe to assume, however, that transportation facilities will keep pace with the demand. It is to be hoped also that the uses for which the American fullers earth is adapted may be extended and that the demand will increase.

LIBERTY COUNTY.

Liberty County lies between the Ocklocknee and the Apalachicola Rivers, south of Gadsden County. It reaches to within about 15 miles of the Gulf coast where it joins Franklin County. The northern part of the county along the Apalachicola River, in the vicinity of Rock Bluff Postoffice, reaches an elevation of from 200 to 250 feet. From this part of the county the slope is gradual to the low lands bordering the Gulf. With the exception of an increased thickness of superficial sands, northern Liberty County is similar both geologically and topographically to the adjoining parts of Gadsden County. Sections at Rock Bluff and at Alum Bluff in Liberty County have already been given. Passing south through Liberty County the surface elevation falls off gradually until at Bristol the upland region lies not more than from 80 to 100 feet above the river, while a few miles beyond Bristol the lowlands of the coastal region appear.

The Chattahoochee limestone passes beneath the river at Rock Bluff. On Rock Creek and Sweetwater Creek and its tributaries the blue and calcareous sands and fullers earth of the Rock Bluff section are exposed. The Miocene marls which come in at Alum Bluff dip toward the south and pass beneath the river below Bristol. Although exposures are not numerous, these marls underlie the county and reappear along the Ocklocknee River on the east boundary. Aside from the bordering rivers, Telogia Creek and New River are the largest streams of the county. New River heads in central Liberty County, while Telogia Creek reaches north into Gadsden County.

NOTES ON FULLERS EARTH.

Fullers earth as indicated on the map, occurs at Rock Bluff and along the headwaters of Rock and Sweetwater Creeks. The section at Rock Bluff (p. 273) will serve to illustrate the conditions of occurrence as seen in the northern part of Liberty County. The streams tributary to Rock Creek and to Sweetwater Creek cut deep channels in passing through the sands lying under the fullers earth. A section of this character is well seen on Spring branch which heads at Rock Bluff Postoffice and flows into Sweetwater Creek; and in a branch flowing in the opposite direction from the divide, also on a small branch heading on section 27, T. 2 N., R. 7. W.

LEON COUNTY.

Leon County lies to the east of Gadsden County extending from the State line and joining Wakulla County on the south and Jefferson County on the east. Leon County differs from Gadsden County in some important respects, both geologic and topographic. In Leon County limestone lies nearer the surface than in Gadsden County. The result is the formation by solution of large lake basins of which Lakes Jackson, Lafayette, Iamonia and Miccosukee are examples. Instead of well established surface drainage with many streams fed by springs, the drainage is largely subterranean, the rainfall entering the limestone. Underground solution therefore predominates over surface erosion. At Tallahassee and at places throughout the interior of the county generally an elevation of about 200 feet is reached.

The red sands, corresponding to the red sands of Gadsden County, are medium coarse, but not so coarse as those found along the Apalachicola. The clays beneath these sands are less conspicuously developed, and are in places absent. Inclusions of a gray calcareous sandstone in the red sands are very numerous. These sandstone inclusions, however, are not confined to Leon County as similar inclusions are found also in Gadsden County.

NOTES ON FULLERS EARTH.

In Leon County the fullers earth has been traced as far east as Tallahassee, having been obtained from a well in the southwest quarter of section 35, T.1 N., R. 1 W. Fullers earth is also found thirteen miles west of Tallahassee on section 26, T. 1 N., R. 3 W. The deposits here overlie gray calcareous sands similar to the sands at Rock Bluff. Fullers earth may be expected along the Ocklocknee River in this part of the county as far as Jackson's Bluff or below.

COLUMBIA COUNTY.

Columbia County extends from the Santa Fe River on the south to the northern line of the State and has a total area of 792 square miles. To the south the county extends into the hard rock phosphate section. The southern part of the county has a rolling topography with numerous sinks and underground cavities. The surface elevation of this section does not exceed 100 feet above sea level, although the central part of the county is higher, approaching 200 feet in general elevation. The underlying limestone in central Columbia County is sufficiently near the surface to permit of occasional sinks and disappearing streams. The extreme northern part of the county is of the flat woods type.

NOTES ON FULLERS EARTH.

At High Falls about eight miles southeast of Lake City sandstones occur, which in lithologic character resemble those associated with the fullers earth.

ALACHUA COUNTY.

Alachua County, in north central peninsular Florida, having an area of 1,283 square miles, presents considerable diversity of soil and topography. The western two-fifths of the county has with the exception of some "flat-woods" a rolling surface. In this part of the county the Vicksburg formations lie either at or near the surface and as a result the rainfall passes rapidly into the earth. The elevation of this part of the county is from 70 to 90 feet.

Northeastern Alachua County, from Hague past Gainesville to Hawthorne, has an elevation of from 150 to 200 feet. Santa Fe Lake from which the Santa Fe River takes its origin rests upon this plateau. The Vicksburg limestone is seldom exposed in this section, being covered by later formations. These later formations are water bearing and most of the wells of the county northeast of Gainesville terminate in them without reaching the Vicksburg. Paynes Prairie together with the basins in the southeastern part of Alachua County represent an area in which underground solution has greatly reduced the original surface level. At an earlier stage the drainage from this part of the county passed off through Orange Lake and the Oklawaha River to the St. Johns River, the tributaries of the drainage system taking their origin in what is now the plateau region of northeast Alachua County. The soluble Vicksburg limestone underlying this section was removed by solution more rapidly than the less soluble rocks to the east with the result that the basin has now been lowered to a level of about sixty feet which is equal to or below that of the former outlet through Orange Lake, and the drainage now passes off through sinks. When the sink is clogged the prairie becomes a lake. Under extremely heavy rainfall the lake would probably rise to a level permitting escape through its former outlet.

NOTES ON FULLERS EARTH.

The occurrence of fullers earth in the Devil's Millhopper, six miles northwest of Gainesville, in Alachua County, was noted by Vaughan as early as 1901.[1] The following section measured with a hand level was made at this place. The top of this section as shown by the topographic map is about 180 feet above sea.

Section at the Devil's Millhopper.

7.	Covered and sloping	25	feet.
6.	Yellowish phosphatic limestone	15	feet.
5.	Bluish-green sandy marl	8	feet.
4.	Gray and blue sands and impure fullers earth	40	feet.
3.	Yellowish limestone	13½	feet.
2.	Sandstone	4½	feet.
1.	Whitish limestone, weathering yellow	5	feet.
		111	

At the city pumping plant two and a half miles southeast of Gainesville, fullers earth was also observed. The fullers earth here is associated with a calcareous sandstone.

MARION COUNTY.

Marion County, in central peninsular Florida, has a total area of 1,640 square miles. The greater part of the county is characterized by a rolling surface with low rounded hills. The western half of the county has few or no surface streams, the surface sands and sandy clays permitting the water to pass directly into the limestone beneath, thus supplying the large springs of this county. Rock phosphate occurs extensively in the western part of Marion County. The rounded hills of the interior of the county reach an elevation of from 100 to 150 feet and in some instances to 200 feet.

---

[1] U. S. Geol. Surv. Min. Res., 1901, p. 932, 1902.

NOTES ON FULLERS EARTH.

Fullers earth has been located at three points in Marion County. The most northern place of occurrence is near Fairfield. The fullers earth at this place was reached in a well, according to the owner, B. S. Quarterman, at a depth of eleven feet. Samples from the vicinity of Fairfield have also been received from M. O. Lewis.

Fullers earth was obtained by E. C. McLeod on his property near Kendrick. Pits put down by Mr. McLeod indicate fullers earth over a considerable territory in this section.

Fullers earth samples were obtained from a sink known locally as the "Grotto," near Belleview, in the southern part of Marion County. The section at this sink is as follows: The measurements were made by a hand level.

Section at Sink Near Belleview.

7.	Yellowish sand	4	feet.
6.	Yellowish sandy clay	15	feet.
5.	Covered and sloping	21¼	feet.
4.	Decayed limestone with fullers earth inclusions	7½	feet.
3.	Fullers earth	4¾	feet.
2.	Gray sand	3¼	feet.
1.	Phosphatic sandy limestone, containing rounded, dark colored, phosphatic pebbles	2½	feet.
		58¼	feet.

MANATEE COUNTY.

Manatee County lies along the Gulf coast of southern peninsular Florida. This county lying near the coast is comparatively level and of but slight surface elevation. Manatee River crosses the county from west to east near the northern part. Miakka River flows through the southern part of the county, entering Charlotte Harbor.

NOTES ON FULLERS EARTH.

Fullers earth has been mined for several years near Ellenton, in Manatee County. Above the fullers earth at this locality, conformable with it, and in fact grading into it, is a stratum variable both in thickness and in character. Ordinarily it is a calcareous, sandy, clayey stratum being apparently disintegrated by decay. When of this character it is from one to four or five feet in thickness. Elsewhere this stratum is harder and more calcareous, being an impure marly limestone four or five feet in thickness. Several prospect holes placed near each other showed in one instance the variation of this stratum from soft clayey carcareous material to a hard limestone rock. This change occurred within a radius of twenty or thirty feet. This stratum contains a few fossils preserved as casts and molds. Occasional chunks or layers occur which contain fairly well preserved fossils. The top surface of this stratum is clearly eroded uneven and represents an erosion unconformity. This is shown in every section observed, both where the stratum is soft and clayey and where it is a hard limestone.

On top of this stratum is usually found a conglomerate layer consisting of bones and pebbles. This stratum is not invariable, but traces of it can usually be found. In some places it is from one to two feet thick.

Lying on the bone pebble stratum is a sandy or sometimes clayey stratum becoming distinctly peaty above. This stratum is rarely if ever absent, although it varies in thickness, both as to the thickness of the peat and the thickness of the clayey or sandy lower part. Above this is the surface sand, usually loamy, and from one to two feet thick.

Immediately underlying the fullers earth stratum is a close grained marly limestone. This limestone contains a few fossil shells preserved as molds. Occasionally as determined from a well near the pit, indurated chunks or layers contain somewhat better preserved molds and impressions. The top of this limestone, where seen, was so far as could be determined, level. The break between the limestone and the fullers earth is distinct, but indicates, apparently, merely a change of conditions, and probably does not represent an unconformity.

The fullers earth stratum is variable in thickness. Where worked it is 6½ to 7 feet thick, elsewhere it thins and may disappear. Such an interruption of the stratum occurs between the east and the west pit.

The following section was obtained in the Atlantic Refining Company's pit:

Section in Pit of Atlantic Refining Company.

7.	Dark colored sandy soil	1 foot.
6.	Dark carbonaceous stratum	1 foot.
5.	Bone stratum containing manatee ribs and other bone fragments...	2 feet.
4.	Unconformity.	
3.	Sandy calcareous stratum with gravels	4 feet.
2.	Fullers earth	8 feet.
1.	Close grained marl.	

The fullers earth lies apparently conformable upon this marl.

Section in Prospect Hole North of Pit.

5.	Sand and soil	1 foot.
4.	Bone pebble stratum	1 to 2 feet.
3.	Unconformity.	
2.	Marly limestone	9 to 10 feet.
1.	Fullers earth.	

The limestone of No. 2 is apparently the same as No. 3 of the preceding section, but is not so much decayed as in that section.

The following section was obtained at the abandoned pit of the Columbia Fullers Earth Company, about two miles northeast of Ellenton:

Section in Pit of Columbia Fullers Earth Company.

Surface sand and soil	1¾ feet.
Dark carbonaceous sands	1¾ feet.
Blue calcareous clay, with occasional bone fragments	4 feet.
Fullers earth reported to be	6½ to 7 feet.

The fullers earth of Manatee County, like that of Gadsden County, is probably, as stated in the report on Stratigraphic Geology, (p. 92), of Upper Oligocene age.

EXTENT AND AMOUNT OF FULLERS EARTH DEPOSITS IN FLORIDA.

From the localities given above at which fullers earth is known to occur it is apparent that these deposits are to be expected over a large extent of territory in Florida reaching as far west at least as the Apalachicola River and as far south as Manatee County.

An estimate of the total amount of workable fullers earth in the State is impossible at the present time. The workable fullers earth of Gadsden County alone has been estimated on a preceding page to be sufficient to supply the demand for this grade at the present rate of consumption for about 500 years. Other sections of the State at which fullers earth may be expected to occur have not yet been examined in detail.

INDEX.

PAGE.
Abes Spring, section at ... 118
Administrative report ... 13
Aeolian deposits ... 159
Agassiz, Alexander ... 26, 177, 211, 215
Agassiz, Louis ... 26, 211, 214
Alachua clay, description of ... 133
    list of fossils from ... 136, 137
Alachua County, fullers earth of ... 287
    phosphates of ... 239
    limestones of ... 248
Allapattah flats ... 189
Allen, John H., cited on the Tampa limestone ... 85
Alluvial deposits ... 157
Alum Bluff formation, description of ... 91, 275
Alum Bluff, sections of ... 93, 275
American Fertilizer, statistics from ... 236
Anastasia Island, coquina of ... 246
Apalachicola group, description of ... 67
Apalachicola River ... 265
Apalachicola, well record at ... 153
Arcadia, section at ... 128
Argyle, section at ... 106
Arkansas, production of phosphates by ... 237
Aspalaga Bluff, sections of ... 81, 82, 271
Bailey, J. W. ... 50, 54, 85
Ball clay, occurrence of ... 242
Bassler, R. S., cited on thickness of Vicksburg limestone ... 53
Beach deposits ... 158
Bear Creek, section on ... 283
Bellair road, section on ... 144
Belleview, section at ... 289
Black Creek, exposures on ... 112
    phosphates of ... 240
Blackwelder, E. ... 222
Blair, A. W. ... 245
Bone Valley gravel, description of ... 138
Bradford County, phosphates of ... 239
Brick-making clays ... 243
Bridges, B. H., analyses by ... 272, 276
Brooker, section at ... 240
Buck Key, record of well at ... 206
Building stone ... 246
Caloosahatchee marl, description of ... 123
Capes ... 42
Caverns ... 32
Chattahoochee formation, description of ... 74, 277
Chattahoochee Landing, sections at ... 79, 80, 267
Chattahoochee limestone, dip of ... 277
    folds in ... 277

Page.
Chemical deposits 159, 250
Chipola marl, description of 102
Choctawhatchee marl, description of 114
    fossils from 117, 120, 121
Citrus County, phosphates of 235
Clapp, F. G. 25, 27
Clark, Frank 27
Classification of soils 44
Clay County, phosphates of 240
Clearwater, section at 90
Coastal swamps in Southern Florida 193
Coleman, R. B. 261
Columbia County, limestones of 248
Concrete, material for 247
Conrad, T. A. 50, 62, 84, 85, 214, 218
Continental border 40
Coquina 153, 225, 246
Coral reefs 40, 177, 229
Cowles, H. C. 266
Cox, E. T., cited on phosphates 235
Cox, N. H. 3
Crill, Dr. E. S. 27
Crooked Creek, section on 283
Dall, W. H. 26, 47, 49, 50, 51, 53, 54, 55, 61, 66, 67, 68, 69, 71 72, 75, 78, 85, 88, 90, 102, 107, 222, 230, 266
Dana, J. D. 216
Darling Slide, section at 119, 120
Darton, N. H. 204
Davis, C. A. 244
Day, D. T. 259
Devil's Millhopper, section of 288
Diatomaceous earth 244
Dunes of Southern Florida 182
Edgar, well record at 243
Ecphora beds 108
Eldridge, George H. 26, 34, 66
Ellenton, sections at 101, 290
Elevation of the Everglades 190
Ellis, R. N. 113
Erosion features 38
Everglades 31, 178, 189
Featherstonhaugh, G. W. 218
Financial statement 17
Florida, early settlements 25
Florida, elevations in 29
    general topographic features of 28
Florida reef 196
Florida State Experiment Station, cited on use of lime 45
Foerste, Aug. F. 53, 68, 75, 266
Four-Mile Creek, Calhoun County, section at 120
Fossiliferous marls, description of 146
Fullers earth, localities of 282, 286, 288, 289, 290

Page.
Fullers earth, report on.......... 257
Gadsden County, fullers earth deposits of.......... 281
geology of 263
phosphatic sandstone of 239
topography of 261
Gainesville, section at 135
Gatzlaff, section at 283
General geologic history of Florida.......... 162
Geology of Florida, table of formations.......... 49
Geology of Southern Florida.......... 202
Gray sand 152
Griswold, L. S. 177, 211
Gulliver, F. P., cited on formation of tidal runways.......... 42
Gunter, Herman 13, 257
Harper, R. M. 13, 244
Harris, G. D. 222, 266, 272
Haven, H. C., well records by.......... 27
Hawthorne formation, description of.......... 69
Heilprin, Angelo 26, 62, 66, 85
Hernando County, phosphates of 235
Highland, altitude of 29
Hillsboro County, phosphates of.......... 235
Holcomb, W. D., well records by.......... 27
Holland, section of well one mile west of.......... 121
Holmes County, limestones of.......... 245
Hovey, E. O. 216, 220
Hughes, Wm. E., well records by.......... 27
Human remains in Florida.......... 160
Hunt, E. B. 214, 216, 229
Infusorial earth 244
Ingraham, J. E. 178, 191
Iowa, production of phosphate by.......... 237
Jackson's bluff, section at..........114, 122
Jackson County, limestones of.......... 245
Jacksonville formation, description of.......... 108
Jacksonville, well records from.......... 109
Jefferson County, phosphates of..........238, 239
Johnson, L. C. 46, 63, 265
Jumeau, P., analyses by.......... 241
Kaolin 242
Kerr, W. C. 85
Key Largo limestone 214
Keys of Southern Florida.......... 195
Key Vaca, record of well at.......... 204
Key West oolite, description of.......... 218
Key West, record of well at.......... 206
Knoxhill, log of well near.......... 106
Kost, John 239
Krome, W. B. 178, 191
Labelle, section at 126
Lacustrine deposits 158
Lafayette County, phosphates of.......... 238

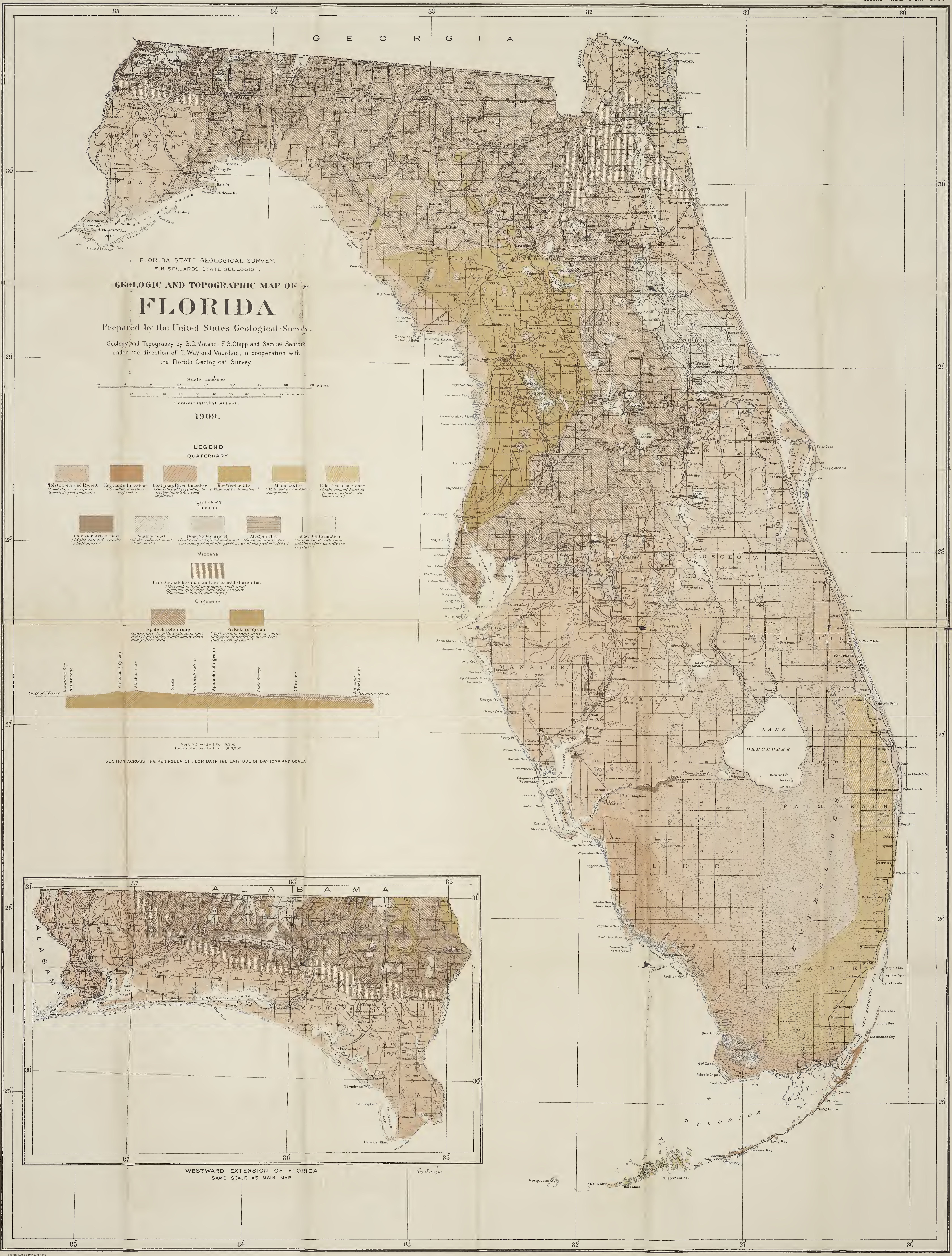
PAGE.

- Lafayette formation, description of ... 141, 263
- Lake City, altitude of ... 29
  - section at ... 73
- Lake County, kaolin of ... 242
- Lake Okeechobee ... 189
- Lake region of Florida ... 32
- Lakes of Florida ... 31, 38
- Langdon, D. W. ... 50, 67, 68, 90, 265
- Laporitieres Spring, section at ... 90
- LeConte, John ... 61, 214
- Leon County, fullers earth of ... 286
  - phosphates of ... 239
- Levyville formation ... 63
- Liberty County, fullers earth of ... 286
  - phosphates of ... 238
- Lime ... 245
- Limestone, ground ... 245
- Loss of phosphate in mining ... 240
- Lostmans River limestone, description of ... 222
- McCallie, S. W. ... 67
- McClelland's farm, section at ... 103
- McCullough's Bridge, section at ... 144
- McGee, W. J. ... 265
- MacGonigle, Dr. J. N. ... 27, 178
- Malachite, occurrence of ... 250
- Mangroves ... 194
- Manatee County ... 289
- Marathon, record of wells at ... 205
- Marls in Southern Florida ... 228
- Matson, G. C. ... 25, 27, 178
- Marion County, fullers earth of ... 289
  - limestones of ... 248
  - phosphates of ... 235
- Marianna, section at ... 57
  - well record at ... 57
- Marianna limestone ... 52
- Maury, C. J. ... 56, 63, 78, 266, 268
- Meredith, J. C. ... 27, 178
- Merrill, G. P. ... 257
- Middleburg, section 2 miles above ... 112
- Miami oolite ... 211, 246
- Miliolite limestone ... 66
- Mineral-bearing lands, relation of the Survey to ... 15
- Mineral matter removed in solution ... 33
- Mineral industries ... 235
- Miocene deposits ... 106
- Miocene underlying Southern Florida ... 207
- Mortar, materials for ... 247
- Mossyhead, altitude of ... 30
- Nashua marl, description of ... 128
  - fossils from ... 130, 131, 132, 133
- Natural bridges ... 36

PAGE.
Near Alexander, well records by.... 27
Nicholson, section at 284
Nummulitic limestone 59
Oak Grove sand, description of.... 104
Ocala limestone, description of.... 59
Okeechobee 31
Okefinokee swamp 29
Ocklocknee River 279
Oligocene deposits 50
Oligocene underlying Southern Florida.... 207
Orange City, section at.... 149
Orient, section at 148
Origin of the Everglades.... 193
Origin of Florida oolites.... 221
Osprey, section at 161
Oyster reefs 230
Palm Beach, record of well at.... 204
Palm Beach limestone, description of.... 209
Peace River, section on.... 128
Pearce, H. W., well records by.... 27
Peat 13, 228, 243
Peninsular limestone, description of.... 52
Pettigrew, Edward, well records by.... 27
Phosphate 235
Pinelands of Southern Florida.... 181
Planorbis rock 153
Pleistocene formations 146, 208
    lists of fossils from....148, 149, 150, 151
Pleistocene and Recent History of Southern Florida.... 231
Pliocene deposits 123, 141
Pliocene underlying Southern Florida.... 207
Polk County, kaolin of.... 242
    phosphates of 235
Porter, J. T. 258
Pre-Pleistocene formation of Southern Florida.... 203
Pumpelly, Raphael 75, 77, 266
Putnam County, kaolin of 242
Quaternary formations 145
Quincy, sections at....97, 98, 282
Recent formations 157, 228
Recent changes of level.... 201
Reports, distribution of 14
Ries, H. 242
River Junction, sections at....83, 84, 96, 145, 269, 270
Rivers of Florida 30
Rock Bluff, sections of 97, 273
Rock Hill, section at.... 145
Rock Springs, miocene deposits of.... 114
Rose, R. E., cited on rock underlying the Everglades.... 193
St. Augustine, well record at.... 113
    coquina at 246
St. Augustine road, section on.... 144

PAGE.
St. Johns River, elevation of 29
Sand bars 40
Sand dunes 37, 39
Sand-lime brick 245
Sands of Southern Florida 226, 229
Sanford, Samuel 28, 177
Sellards, E. H. 13, 33, 66, 70, 235, 257
Shaler, N. S., cited on geology of Florida 46
Shell Bluff, section at 105
Shell deposits 250
Shoal River marl, description of 104
Shore lines 40
Shore line topography of Southern Florida 198
Sounds 41
Sink holes 34
Smith, Buckingham 211
Smith, E. A. 26, 50, 55, 67, 239, 266
Smith, George Otis 23
Solution, amount of 33, 187
Soils of Florida 43
Soil surveys 44
Sopchoppy limestone, description of 92
South Carolina, production of phosphate by 237
Springs 37
Swamps of Florida 31
Stanley-Brown, J. 115
State Chemist, analyses by 15, 241, 272, 276
State Geologist 13
Stephenson, L. W. 73, 147
Structure of Florida 46
Sumter County, limestone of 248
Suwanee River, sections on 73
Suwanee County, phosphate of 235
Swamps in Southern Florida 188
Tallahassee, altitude of 29
    sections at 99
Tampa formation 84
Tampa, sections at 90, 91
    well record at 89
Taylor County, phosphates of 238
Tennessee, production of phosphate by 237
Terraces 39
Tertiary formations 50
Tests of fullers earth 259
Thickness of Pleistocene 227
Tidal inlets 41
Tidal runways 41
Topography of Florida 28, 179
Trail Ridge 29
Tripoli 244
Tuomey, M. 50, 75, 85, 211, 214, 218
United States Department of Agriculture, co-operation with 14

PAGE.
United States Geological Survey, co-operation with 14
  fuel tests by 13
Utah, production of phosphate by 237
Van Horn, F. B. 233
Vaughan, T. W. 26, 53, 58, 76, 77, 79, 90, 95, 96, 104, 105, 106, 114, 144, 255, 266, 288
  identification of fossils by 112, 117, 120, 121, 130, 132, 133, 149, 150, 151
Vermetus rock 154, 158
Vicksburg group, description of 50
Vicksburg limestones, as building stone 246
Wagner Free Institute of Science, publications by 25
Wakulla County, phosphates of 239
Walker, H., well records by 27
Walton County, limestones of 245
Washington County, limestones of 245
Waste and growth of the mainland and keys 200
Webb, Dr. DeWitt 27
West Palm Beach, well record at 152
White Springs, section at 73, 74, 100
Whiting, Henry 214
Whitney, Milton, cited on classification of soils 44
Wiley's Landing (Georgia) 80
Willcox, Joseph 62
Willis, Bailey 222, 224
Worm rock 230
Wyoming, production of phosphate by 237
Yellow River, section of bluff on 104
Yellow sand 155


GEORGIA
85
84
83
82
81
80
30
29
28
27
26
25
Cape St. George
Apalachicola Bay
St. George Sound
Lake Okechobee
Palm Beach
Everglades
Dade
Lee
De Soto
Manatee
Osceola
St. Lucie
Hillsborough
Polk
Orange
Volusia
Citrus
Hernando
Levy
Marion
Taylor
Madison
Bradford
St. Augustine
Cape Canaveral
Key West
Dry Tortugas
Marquesas Keys
Florida Bay
Cape Sable
Miami
LEGEND
QUATERNARY
Pleistocene and Recent (Sand, clay, marl, coquina, limestone, peat, muck, etc.)
Key Largo limestone (Coralline limestone, reef rock)
Lostmans River limestone (Dark to light crystalline to friable limestone, sandy in places)
Key West oolite (White oolitic limestone)
Miami oolite (White oolitic limestone, sandy beds)
Palm Beach limestone (Light colored hard to friable limestone with loose sand)
TERTIARY
Pliocene
Caloosahatchee marl (Light colored sandy shell marl)
Nashua marl (Light colored sandy shell marl)
Bone Valley gravel (Light colored gravel and marl containing phosphatic pebbles)
Alachua clay (Greenish sandy clay weathering red or yellow)
Lafayette formation (Clay or sand with some pebbles, colors usually red or yellow)
Miocene
Choctawhatchee marl and Jacksonville formation (Greenish to light gray sandy shell marl, greenish gray clay, and yellow to gray limestones, sands, and clays)
Oligocene
Apalachicola group (Light gray to yellow siliceous and cherty limestones, sands, sandy clays and fuller's earth)
Vicksburg group (Soft porous light gray to white limestone containing marl beds and layers of chert)
Gulf of Mexico
Waccasassa Bay
Pleistocene
Vicksburg group
Alachua clay
Ocala
Ocklawaha River
Apalachicola group
Lake George
Pliocene
Daytona
Pleistocene
Atlantic Ocean
Vertical scale 1 to 10,000
Horizontal scale 1 to 1,000,000
ALABAMA
87
86
85
31
30
Choctawhatchee Bay
Santa Rosa Island
Washington
St. Andrews
St. Josephs Pt.
Cape San Blas

FLORIDA STATE GEOLOGICAL SURVEY.
E. H. SELLARDS, STATE GEOLOGIST.

GEOLOGIC AND TOPOGRAPHIC MAP OF

FLORIDA

Prepared by the United States Geological Survey.

Geology and Topography by G. C. Matson, F. G. Clapp and Samuel Sanford
under the direction of T. Wayland Vaughan, in cooperation with
the Florida Geological Survey.

Scale $\frac{1}{1,000,000}$

10 0 10 20 30 40 50 60 70 Miles

10 0 10 20 30 40 50 60 70 80 Kilometers.

Contour interval 50 feet.

1909.

SECTION ACROSS THE PENINSULA OF FLORIDA IN THE LATITUDE OF DAYTONA AND OCALA.

WESTWARD EXTENSION OF FLORIDA
SAME SCALE AS MAIN MAP

A B GRAHAM CO LITH WASH D C

SMITHSONIAN LIBRARIES
3 9088 01891 7708